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Safeguards and Nonproliferation Considerations Relevant to Fuels Refabrication and Development Program

T. I. McSweeney
J. A. Powers

September 1979

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SAFEGUARDS AND NONPROLIFERATION CONSIDERATIONS RELEVANT TO FUELS REFABRICATION AND DEVELOPMENT PROGRAM

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1.0 INTRODUCTION

The Fuels Refabrication and Development (FRAD) Program has as its goal "to develop a refabrication technology base for proliferation resistant fuel cycles to a point where the choice of desirable fuel cycles is not limited by refabrication technology." In accordance with this goal, studies are being conducted to fill in the technology gaps presently limiting which refabrication technology could be used in a future facility. Safeguards and proliferation-resistance assessments must be carried out in concert with other program activities in order to meet processing, safeguards, and nonproliferation requirements simultaneously .

Proliferation assessments can influence refabrication designs in two ways. First, proliferation considerations can influence fuel characteristics, which in turn affect the design. Second, basic design features that enhance safeguardability (both domestic and international) must be considered. Spiking and processing of denatured U-233 fall under the first category. Design attributes that improve the detectability of diversion fall under the latter. In this document, only design considerations that enhance domestic and international safeguardability of refabrication designs will be considered. It is recognized that this is a small but very significant part of the broad proliferation issue.

The primary purpose of this document is to initiate the development of domestic and international safeguards design criteria for the FRAD program. In recognition of the fundamental role of these criteria, a workshop was held March 28-30, 1979, at the Pacific Northwest Laboratory* in Richland, Washington. Ten individuals attended this three-day working group

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* The Pacific Northwest Laboratory is operated for the Department of Energy by Battelle Memorial Institute.

meeting; they are listed in Table 1. This report was prepared based on discussions at the workshop and further developed by workshop participants and represents a compendium of workshop submissions, revisions, and reviews performed by workshop participants.

Section 2 provides an overall summary of the findings. Section 3 traces the steps leading toward design criteria, first for domestic safeguards then for international safeguards. The results of discussions during the three-day workshop are included in this section. The report concludes with a discussion of future work required for full integration of safeguards considerations into the FRAD program.

Table 1

FRAD WORKSHOP MEETING

March 28-30, 1979

ATTENDEES

Jim Powers	Bob Sorenson
Fred Forscher	Tom McSweeney
Fred Morris	Mark Mullen
Jim DeMontmollin	Ray Kofoed
Willie Higinbotham	Carl Bennett

2.0 SUMMARY

Early in the FRAD program, it was recognized that safeguards and nonproliferation design criteria were needed to provide guidance to equipment, process, and facility designers. This need was highlighted by the recent attention given safeguards and proliferation. Because of this heightened concern, it was found that design criteria that adequately address safeguards and nonproliferation do not now exist.

For this reason, a three-day workshop was convened to attempt to collect and organize existing information regarding design criteria. This document is a result of that undertaking and the subsequent efforts required to structure the information.

In summary, it was found that domestic and international goals and objectives are reasonably well established. Goals and objectives for evaluating the proliferation resistance of a facility are less firmly defined.

A listing of design criteria for domestic and international safeguards has not been compiled. This document presents a summary of considerations that must be incorporated into design criteria but stops short of developing a comprehensive list of design criteria. One is certainly needed and should be funded as a follow-on effort. Following the development of the design criteria, the next logical steps are the development of evaluation methodologies and acceptance criteria. These also were proposed as logical follow-on activities which would be needed before a major FRAD design activity could be initiated.

3.0 DEVELOPMENT OF DOMESTIC AND INTERNATIONAL SAFEGUARDS GOALS, OBJECTIVES, AND DESIGN CRITERIA

The ultimate goal of the FRAD program is to develop the refabrication technology data base to a point where the choice of desirable fuel cycles is not limited by refabrication technology. This implies that the design activities have been completed to the point where construction of a selected alternative could begin. There are many steps that must be taken to reach this point. Only the first four will be addressed in this section; the remainder will be addressed under "Future Efforts" in Section 4.

The first design activity is to outline a point of reference. Second, a list of assumptions regarding future design requirements must be developed. Then and only then is it possible to discuss goals and objectives. The fourth activity is to develop design criteria.

In this document, each of these activities will be discussed, first for domestic safeguards, then for international safeguards. For both topics, the last section will be termed "considerations for design criteria" rather than "design criteria." The title simply reflects the present status of technology and the limited time and scope of this effort.

3.1 DOMESTIC SAFEGUARDS GOALS, OBJECTIVES, AND DESIGN CRITERIA

Point of Reference

In addressing the issue of domestic safeguards, the present point of reference shows two conflicting elements. Most operating facilities were designed and built in the late 1950's or early 1960's during a period when financial accountability was thought to provide adequate safeguards. Physical security requirements were nonexistent at that time. As a result, safeguards in facilities operating today have been incorporated through retrofitting. Alternatively, numerous studies have been performed that describe safeguards upgrades but stop short of implementing design criteria. Thus, from the current point of reference, the FRAD program could provide the means to test and evaluate safeguards concepts, and ultimately FRAD could design a facility that incorporates safeguards concerns into every aspect of plant operation.

Assumptions

From the present point of reference, it is evident that all future facility designs cannot be based on existing design criteria. Current safeguards design criteria are incomplete. It has to be assumed that future facilities will address safeguards elements. It also must be assumed that development activities will be timed so that safeguards characteristics can be addressed in the design. Lastly, it must be assumed that a set of criteria can be established that provides adequate performance throughout the design lifetime of the facility. Assumptions regarding the nature of the threat and the required performance level of the safeguards system are the most sensitive issues.

The subnational threat is assumed to be posed by a small group of individuals, with objectives ranging from obtaining nuclear weapons materials down to the fabrication of a credible hoax. Objectives with intermediate consequences include dispersal of toxic materials or facility sabotage. The subnational threat is very broad and difficult to limit and characterize. In order to characterize the subnational threat, it is assumed that:

1. The design must consider the threat posed by a small group of dedicated individuals.
2. The host nation has the responsibility to counter the threat posed by the subnational group.
3. Threats considered credible by a subnational group can be classed as follows: overt theft, covert theft, facility takeover, sabotage, and hoaxes.

Goals and Objectives for Domestic Safeguards

In 1975 a study was commissioned by the Nuclear Regulatory Commission to confirm the safeguards objective.(1) Previously, the draft "Generic Environmental Statement for Mixed Oxides Fuel" (GESMO)(2) contained the following statement of the safeguards objectives:

> Safeguards measures are designed to deter, prevent or respond to (1) the unauthorized possession or use of significant quantities of nuclear materials through theft or diversion, and (2) sabotage of nuclear facilities.

The report went further to state that the objective of the safeguards program is to "achieve a level of protection against such acts to insure against significant increase in the overall risk of death, injury, or property damage from other sources beyond the control of the individual." The confirmation study consisted of a series of meetings held to seek consensus on the stated objective. The meetings resulted in three other statements of objectives that differed drastically from each other in form. The content did not appear to be substantially different from the original objective. The only consensus reached regarding the initial statement concerned the use of the word "deter" in an objective statement. It was felt that "prevention is the proper goal even if it is unattainable in the long run." The report went on to state that "deterrence is one means of attempting to prevent diversion (sabotage)."

In 1977 the Nuclear Safeguards Technology Handbook(3) funded by DOE gave the following objective of safeguards:

> Domestic safeguards measures have as their objective the deterrence, detection, and delay of unauthorized activities, as well as appropriate response to these activities should they occur.

Whereas an NRC-funded project drops deterrence in favor of prevention, the later DOE study quoted above makes no mention of prevention. Recent publications make no mention of the objective of safeguards and deal instead with the content of safeguards systems. While the 1975 study may be faulted for not confirming the safeguards objective, at least there was recognition that an objective statement is fundamental to any program. It proposed the following hierarchical structuring of objectives:

1. Global objectives
2. Objectives of the safeguards program
3. Design constraints and performance objectives
4. Scoping activities

This proposal has been largely ignored. Most reports would be classed in Level 3 or 4 of the above list.

Because an objective statement must precede any meaningful endeavor, the following safeguards objective will be used to structure subsequent sections of this report:

> The objectives of safeguards are to prevent or effectively respond to the unauthorized possession or use of significant quantities of nuclear materials through theft or diversion and sabotage of nuclear facilities and to prevent any individual or group of individuals from successfully perpetrating a hoax.

This statement is responsive to the concern expressed in the evaluation of the GESMO statement which concluded that "prevention is the proper goal even if it is unattainable in the long run." The above objective is also responsive to recent concerns regarding hoaxes. Hoaxes are a relatively common occurrence, whereas many other adversary activities are only postulated threats.

Considerations for Design Criteria for Domestic Safeguards

Design criteria can be prepared from the viewpoint of incorporating existing practices in domestic safeguards and determining the gaps that exist and filling them to have a design considered to be the most cost-effective in protecting FRAD facilities against theft of SNM and sabotage. Alternatively, design criteria can be developed from a set of goals and objectives that a safeguards system is to meet, independent of existing practices, and which, when developed, may or may not include the same elements of current and planned safeguards. While the latter approach is more purist and theoretically should yield the most cost-effective, integrated, and defensible system, it is not practical. Because it appears to downplay, or ignore, current safeguards that have evolved over the past 10-15 years and have been accepted by users and regulators alike, it would be difficult to obtain agreement from the safeguards community to utilize this approach.

Since the end result should be the same in either case, and since the first option provides the more visible bond to existing safeguards, it is that approach that will be taken here.

Domestic safeguards include both physical protection and material control and accounting and are implemented by the Department of Energy and the Nuclear

Regulatory Commission. There is no stated single objective or set of objectives for domestic safeguards, but descriptive words such as "deter," "detect," "prevent," "respond to," and "recover" convey the purpose of the domestic program and can be used to initiate the development of design criteria. Physical protection defends primarily against the outsider, material control and accounting (MCA) against the insider. Physical protection requirements influence both external and internal plant design; MCA requirements influence only internal design. In the domestic safeguards system, the key words are "prevention" and "timely detection" of overt and covert acts, respectively. Design criteria for domestic safeguards must provide for the prevention/timely detection capabilities of in-place safeguards.

In addition to meeting safeguards goals, objectives and/or requirements, safeguards design criteria must interface satisfactorily with design criteria for environmental protection and safety as well as the operational functions of the facility. The most difficult requirement for safeguards design criteria to meet is that the criteria last the test of time, that they provide the facility designer with information to enable safeguards to be designed into the facility <u>and</u> assurances that at the future date when the facility is ready to operate, the criteria will not be out of date. The time span between facility design and facility operation is on the order of 10 years. There is no way to predict a threat 10 years in advance, much less characterize it. Only by defining the threat in broad general terms and by incorporating flexibility into the design criteria to accommodate a range of threats can a degree of assurance be obtained that the design criteria will still be functional when the facility begins operation.

In the section on goals and objectives, three classes of threat were identified (overt attack, covert attack, and hoaxes). The safeguards system must develop a strategy for countering each class of threat based on some mixture of the functional safeguards objectives. The following paragraphs describe the approach taken to counter each class of threat.

Overt Attack

The basic defensive structure for detecting and responding to overt attacks is incorporated into the physical protection system. This system includes the definition of a series of protective zones which must be bounded by physical barriers with controlled access of personnel and material. Primary protection zones for a fuel refabrication plant are shown in Table 2, reproduced from a report prepared by Fienning, et al., of Sandia.(4)

The purpose of the discrete zones is to control and monitor the flow of material and the movement of people. Protective zones include material access areas containing SNM and also vital areas that contain essential equipment but no SNM. Movement of personnel into a zone will be limited to those requiring access to that specific zone. Portal entry and exit systems will be designed to detect unauthorized entry and deny entry to such individuals. The movement of material across zone boundaries will be similarly restricted and monitored so only approved transfers occur. The following elements form the basis of a physical security system:

- Barriers
  - Side Boundary Barrier
  - Protected Area Barrier
  - Building Perimeter Barrier
  - Material Access and Vital Area Barriers
  - Material Containment Barriers
  - SNM Containers
  - Activated Delay Mechanisms
- Portal Entry & Exit Control
  - Personnel Portal
  - Vehicle Portal
- Intrusion Detection & Assessment

Table 2

PRIMARY PROTECTION ZONES OF THE MAIN PRODUCTION STREAM

PROTECTION ZONE	SAFEGUARDS PURPOSE	SPECIFIC SAFEGUARD CONCERNS (in addition to general concern in protecting against outside attack)
1	To protect the facility from unauthorized intrusion or exit of personnel or contraband and to provide an acceptance process for vehicles carrying loads of PuO_2.	Introduction of attackers and high explosive by arriving vehicles, including substitution of a vehicle containing saboteurs, thieves, or their supporting equipment (e.g., arms or high explosives) for an authorized vehicle.
2	Protected receiving and storage of plutonium oxide containers.	Removal of PuO_2 from container or sabotage of container by the unloading crew or by an intruder. Removal of full container by inadvertance or by substitution of return empty container by full one.
3	Management of the bulk material unloading and continuous flow fuel fabrication process.	Largest concern is with theft or dispersal of plutonium oxide. Substantial concern is with theft of mixed oxide or fuel pellets, and with industrial sabotage involving the dispersal of plutonium products.
4	Monitor the integrity of the fuel rods and protect them during the inspection, storage, and assembly processes.	Theft of complete fuel rods and fuel assemblies. Removal or substitution of pellets from faulty or sabotaged fuel rods. Substitution of rods (and covert disassembly) using components introduced from tube preparation area or from outside.
5	Security of fuel-rod loading and shipping process.	As above, plus control of fuel assembly vehicle loading and dispatch.

A complete set of physical security requirements is contained in 10 CFR[(a)] Part 73, "Physical Protection of Plants and Materials." As stated in the 10 CFR, these requirements are "for the purpose of protection against acts of industrial sabotage and protection of special nuclear material against theft by establishment and maintenance of a physical protection system of: (1) protective barriers and intrusion detection devices at fixed sites to provide early detection of an attack; (2) deterrence to attack by means of armed guards and escorts; and (3) liaison and communication with law enforcement authorities capable of rendering assistance to counter such attacks." Part 73 contains physical security requirements for strategic special nuclear material, special nuclear material of moderate strategic significance, and special nuclear material of low strategic significance.

The physical security requirements for strategic special nuclear material (SSNM), also referred to as Category I material, apply to quantity and type of material according to the following definition: HEU, U-233 or Pu alone or in any combination totaling 5,000 grams or more computed by the formula, grams = (grams contained U-235) + 2.5 (grams U-233 + grams Pu). The requirements are contained in section 73.40 for FRAD facilities and include the following:

1. Establishment of a security organization to protect the facility against theft and sabotage;
2. Establishment of protected, vital and material access areas;
3. Separation of perimeter and internal barriers to allow monitoring of the intervening space;
4. Establishment of an isolation zone around the perimeter barrier for monitoring purposes;
5. Location of parking facilities outside of isolation zone;
6. Control access of vehicles into protected area;
7. Control access and egress of personnel into protected, vital and material access areas;

(a) Title 10, Code of Federal Regulations-Energy.

8. Prevent entrance into the protected area of firearms, explosives, and incendiary devices, or other items which could be used for industrial sabotage;
9. Install redundant central alarm stations, one of which shall be located within the protected area;
10. Provide redundant offsite communications capability; and
11. Provide redundant power supplies to all security related equipment.

Special nuclear material of moderate strategic significance (also called Category II materials) is SSNM of less than the formula quantity but more than 1 kg of HEU or more than 0.5 kg of Pu or U-233 or in a combined quantity of more than 1 kg when computed by the formula, grams = (grams contained U-235) + 2 (gram U-233 + grams plutonium); or 10 kg or more of less than 20% but more than 10% enriched uranium. Physical security requirements for material of this type and quantity are the following (from paragraph 73.47):

1. Establish illuminated controlled access areas in which the material is to be processed;
2. Establish vault type room or security cabinets for storage of the material;
3. Establish a security organization to assess and respond to any unauthorized penetrations or activities in the controlled access areas; and
4. Provide an offsite communications capability.

SNM of low strategic significance (also called Category III material) is less than a formula quantity of Category II material but more than 15 grams of HEU, U-233 or plutonium, separately or in combination, or less than 10 kg but more than 1 kg of 10% to 20% enriched uranium, or 10 kg or more of uranium enriched to less than 10%. Physical security requirements for this material, also from 10 CFR, paragraph 73.47, are the following:

1. Establish controlled access areas for use and storage of the material; and
2. Establish onsite or offsite organization to respond to unauthorized penetration or activities.

These physical security requirements for Categories I, II, and III material exist for different purposes. The Category I (SSNM) requirements have evolved in stages from the relatively loose industrial security practices that existed in the early 1970's to the current system that is reflected in international guidelines (INFCIRC/225, Rev.1)(5) as well. Changes have taken place in domestic requirements primarily as a result of changes in the perceived threat of theft and sabotage. Since a threat is composed of individuals with certain behavioral characteristics and material resources, it is understandable and expected that the threat will vary with time. The Department of Energy and the Nuclear Regulatory Commission have supported a number of studies to characterize potential threats. A recent NRC publication contains much of the substantive information from both government and nongovernment reports. This publication, "Generic Adversary Characteristics Summary Report" (John B. Stewart, Jr., et al., NUREG-0459),(6) has conclusions that are useful in considering design criteria. They are presented at this point because they influence physical security more than material control and accounting.

1. One of the least likely methods of attack is an overt armed assault;
2. Terrorists and psychotics depend upon a high degree of personal dedication;
3. No single generic adversary group or individual exhibits strength in every characteristic;
4. Physical danger appears to have some deterrent effect on all adversaries with the exception of the psychotic;
5. Organized and professional criminals often try to recruit persons who work inside target facilities to provide them with some form of assistance;

6. The critical characteristic of disoriented persons, white collar criminals, and disgruntled employees is that they tend to operate as insiders;
7. Professional criminals, many terrorist groups, some extremist protest groups, and certain disoriented persons plan carefully before initiating a given criminal mission;
8. The organized crime and miscellaneous criminal adversaries rely upon deception and ruse as tactics to bypass or neutralize security forces and systems;
9. Given that terrorists or organized criminals have chosen to commit a particular crime, the resources (i.e., men, weapons, and equipment) they deploy will be a function of their perception of the operational requirements of the crime;
10. The nature of "threat," in general, is dynamic; adversary behavior and capability appear to be related to prevailing political, economic, and social conditions.

Each of these conclusions is supported by a discussion of the rationale leading up to the conclusion. The reference document should be referred to for these detailed discussions. The reference also contains an "Adversary Characteristics Matrix" which groups 18 characteristics according to organizational, operational, behavioral, and resource categories.

Covert Attack

The protection against theft, diversion, or sabotage by a small group of insiders is the basic responsibility of a coordinated material and personnel control system as shown in Figure 1. This concept has been developed jointly by Sandia and Los Alamos and has been described in many reports. This particular figure is taken from a report by Fienning.(4)

The personnel access control and monitoring performed as part of this system is designed to limit the movement of personnel and thereby limit the opportunities for theft, diversion, or sabotage. Not only should the system be highly

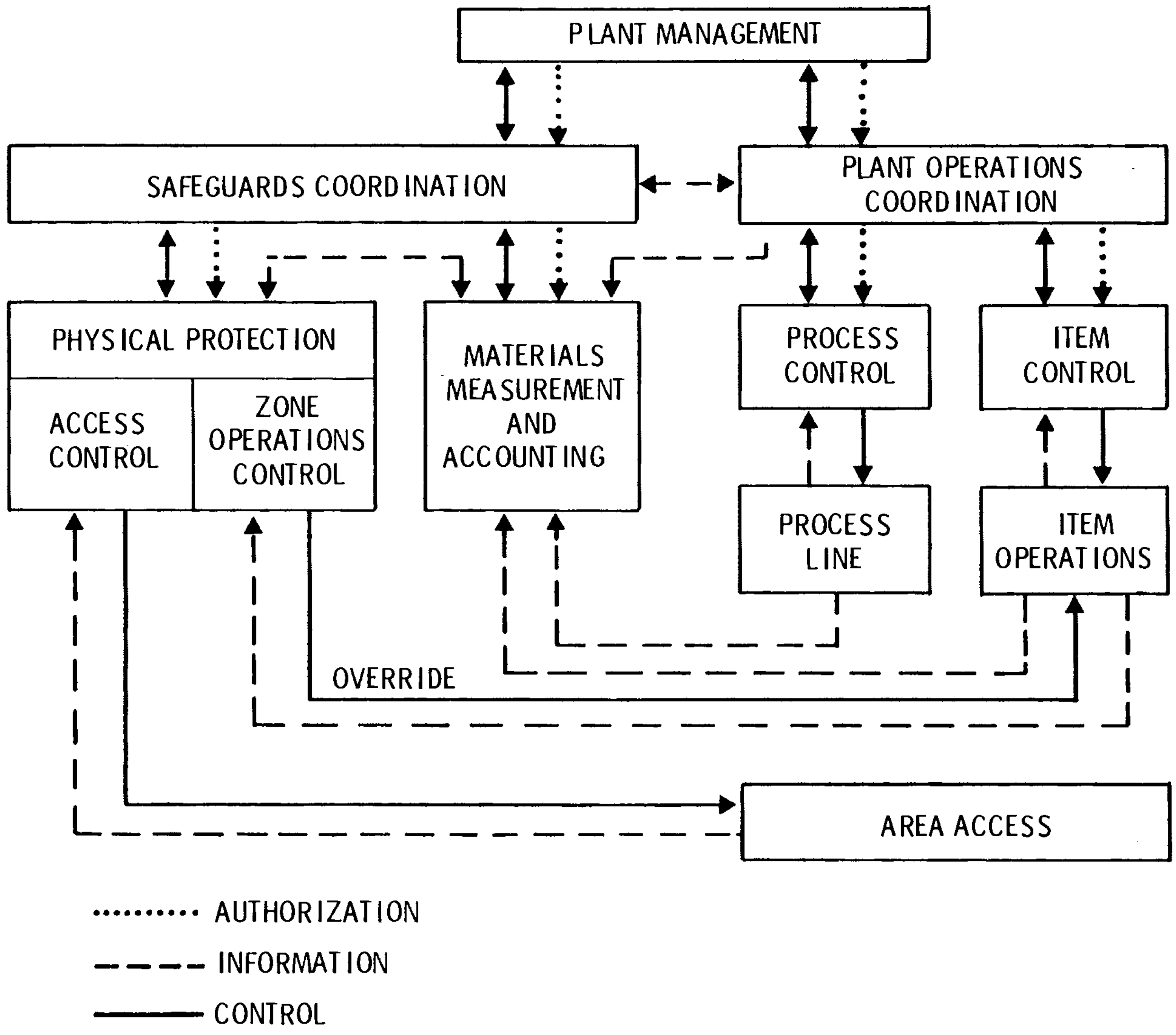

FIGURE 1. Safeguards System Overview

effective in detecting attempts at unauthorized entry, the system should also include random checks to assure the system is effective.

The material control system is much more complex than the personnel control system because the sensitivity of the system is fundamentally limited by measurement uncertainty. Some elements of the measurement control system are shown in Table 3 which was developed at the workshop under the title "Safeguardability Considerations." The absence of a detailed listing of facility design criteria for safeguardability is the most serious limitation facing designers of future facilities. Criteria for protection against covert attack are needed to direct research on advanced facility designs.

Hoaxes

Hoaxes are very difficult to deal with because the adversary has infinite capability and the facility operator always has some level of uncertainty regarding the exact status of the operation. The best protection against hoaxes is provided by systems that assure that:

- There have been no penetrations by an external adversary that haven't been detected and repelled.
- There have been no unauthorized personnel who have gained access to the facility or to protected zones.
- All material is present and in the proper location.

The extent to which these assurances can be realized will minimize the risk from hoaxes.

Additional elements of the domestic safeguards program are the material control and accounting requirements. These requirements provide a degree of protection against covert theft and hoaxes. They are contained in 10 CFR Part 70 - Special Nuclear Material, paragraphs 70.51, 70.57 and 70.58, Material balance,

Table 3
SAFEGUARDABILITY CONSIDERATIONS

- Aspects of visibility
    - Measurability - NDA (W,SA)/Accounting
    - Inspectability/verifiability
        - Vision
        - Availability
    - Multiple activities (duplicate measures)
- Follow-up
- Opportunity for observation/duration
- Containment
- Process controls
- Localization of diversion points
- Running inventory
- Backup systems
- Self-checking

Measurability

- All materials measurable
    - Transfers
    - Inventory
    - Holdup
- Referrable back to standards (traceability)
- MC program
- How often
- How well
- Precalibration
- Integrity of measurements
- Running inventory

How Often

- Often enough to detect Q(t) missing

How Well

- (State of the Art) - poor criteria
- Based on requirement to know where all SNM is to within Q(t)
- Based on cost
    - Effective safeguards
    - Value-impact study

inventory, and records requirements; measurement control program for SNM control and accounting; and fundamental nuclear materials controls, respectively. The requirements of this part apply to licensees authorized to possess one effective kilogram or more of SNM.

The material balance, inventory and records requirements include the following:

1. Keep records showing the receipt, location, disposal, import, export and transfer of all SNM for five years;
2. Establish, maintain and follow written material control and accounting procedures;
3. Perform periodic physical inventories, the period defined according to the strategic nature of the material;
4. Maintain procedures for tamper-safing containers or vaults of SNM not in process;
5. Following an inventory, calculate MUF and LEMUF and reconcile "significant" differences between actual and book inventory;
6. The physical inventory shall be based on measure values.

The measurement control program (paragraph 70.57) requires that certain quality control procedures be established to assure the accuracy of SNM measurements. From a facility design viewpoint, these requirements place no additional constraints or insight beyond those in paragraph 70.51. They do provide detail for designing and equipping an analytical laboratory, but these details are beyond the scope of this effort and should be addressed in a later phase.

The fundamental nuclear material controls (paragraph 70.58) also describe administrative and organizational procedures more than facility design requirements. These requirements need to be considered in terms of record keeping and personnel space design, similar to those of paragraph 70.57. Specific design guidance is contained in this section to the following extent:

1. Establish material balance and item control areas (MBAs and ICAs) in sufficient number to localize nuclear material losses or thefts; and
2. Design a scrap recovery capability so that SSNM scrap measured with uncertainty of ± 10 percent can be reprocessed within six months.

The physical security, adversary characteristics, and material control and accounting requirements can be utilized to develop design criteria if these requirements are first translated into design provisions. It is clear from the requirements that different design provisions and different design criteria will apply to different categories of material, although the MCA requirements generally apply to all SNM.

Category I Material Design Provisions:

A. Provide for the detection of overt attacks by establishing protected areas and by redundant alarm systems;

B. Provide for techniques for assessing the nature of an overt attack;

C. Provide for security force protection while responding to an overt attack;

D. Provide for redundant off-site communications capabilities;

E. Provide for redundant power supplies for all security equipment;

F. Provide for only those structures that process or store SSNM to be inside protected areas;

G. Provide access and egress controls for personnel and vehicles to protected, vital and material access areas;

H. Provide for the rapid inventory of all SSNM in storage and in process;

I. Provide for data generation and record keeping capabilities;

J. Provide for support facilities and areas for all safeguards related functions;

K. Provide for offices and work areas for all safeguards personnel; and

L. Provide for rapid (6 months) scrap recovery.

Category II Material Design Provisions:

A. Provide for the detection of unauthorized access to controlled access areas;

B. Provide for off-site communications capability;

C. Provide for data generation and record keeping capabilities;

D. Provide for inventory of all Category II material in storage and in process;

E. Provide for support facilities and areas for all safeguards related functions; and

F. Provide for offices and work areas for all safeguards personnel.

Category III Material Design Provisions:

A. Provide for controlled access areas;

B. Provide for detection of unauthorized activities;

C. Provide for data generation and record keeping capabilities;

D. Provide for inventory of all Category III material in storage and in process;

E. Provide for support facilities and areas for all safeguards related functions; and

F. Provide for offices and work areas for all safeguards personnel.

3.2 INTERNATIONAL SAFEGUARDS GOALS, OBJECTIVES, AND DESIGN CRITERIA

As mentioned in the introduction, the proliferation issue is very broad and from a technical point of view, it is very difficult to address technical issues without addressing issues of national sovereignty, politics, and economics. Control of proliferation calls for consideration of the proliferation-resistant features of the fuel cycles to be deployed, the strengthening of IAEA safeguards for these facilities, and the exploration of additional multi-aid international institutions. This study will focus primarily on the second element of proliferation resistance: international safeguards. Of the broader issues, some discussion of design features that may provide proliferation resistance will be presented. It is felt that these design attributes can be included under the title "International Safeguards Considerations." A more complete treatment of the broader proliferation issues is the goal of the NASAP(a) studies now in progress and is considered beyond the scope of this report.

The discussion of international safeguards goals, objectives, and design criteria will follow the steps used to develop domestic safeguards design elements. First, the point of reference will be discussed, followed by assumptions, goals and objectives, and considerations for design criteria.

Point of Reference

The concern over proliferation and its relationship to international safeguards ultimately resolves into two concerns: horizontal proliferation and vertical proliferation. The first addresses the issue of a non-weapons state obtaining nuclear weapons capability. The second addresses the issues associated with developing a nuclear weapons arsenal. While both are of concern, at the present time only IAEA safeguards systems exist. The following paragraphs, provided by W.A. Higinbotham, describe the present IAEA safeguards system.(b)

(a) Nonproliferation Alternative Systems Assessment Program (NASAP).

(b) W.A. Higinbotham, Brookhaven National Laboratory, personal communication with J.A. Powers, Teknekron, September 12, 1979.

The IAEA was founded in 1957 to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, as far as it is able, that assistance provided by it or at its request or under its supervision and control is not used in such a way as to further any military purpose."

Subsequent to the establishment of the IAEA, the Board of Governors has approved two major documents which define in more detail the nature of safeguards agreements between a State (i.e., nation) and the IAEA. The first of these (INFCIRC/66/Rev.2, 1968)(7) describes the Agency's safeguards system for nuclear materials and/or facilities submitted under a bilateral or multilateral agreement or unilaterally by a nation. It may apply to some or to all of the nuclear materials and facilities within a nation. The second (INFCIRC/153, 1971)(8) was issued after the Treaty on the Nonproliferation of Nuclear Weapons (NPT) came into effect. A nation signatory to the NPT agrees to accept safeguards on all source and special nuclear material in all peaceful nuclear activities within its territory or under its jurisdiction. Both documents oblige the IAEA to make a determination as to compliance with the terms of the agreement and, where noncompliance has been concluded, to report to the Board of Governors.

Paragraph 28 of INFCIRC/153 states that "the Agreement should provide that the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."

The Agency is authorized to apply safeguards to declared nuclear materials and facilities. Its inspection and surveillance activities are limited so as not to interfere unnecessarily with the operations of the safeguarded facilities. The IAEA is authorized to confirm that nuclear facilities are operated as described in the IAEA-State agreement, but it is not authorized to inspect for clandestine nuclear activities. The Agency is instructed, e.g., in Article III of the NPT, "to avoid hampering the economic or technological development of the parties, or international cooperation in the field of nuclear activities." Thus, the IAEA is not in a position to require that a more proliferation-resistant process be adopted rather than one that is less proliferation-resistant. Individual nations or groups of nations, such as the Nuclear Suppliers' Club, or other international institutions may be able to influence such decisions.

The IAEA is responsible for assuring the international community that nations under its supervision are adhering to their nonproliferation pledge, or to provide "timely warning" to the Board of Governors that it has evidence of a diversion, or that it cannot conclude that no diversion has occurred. It has no ability to interfere with a diversion or to prevent the seizure of nuclear materials by a host nation. A State party to the NPT may "withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country," giving three months notice.

Assumptions

From a technical standpoint, there are two threats of concern in international safeguards. The first is the diversion of nuclear material from a facility by the host nation, and the second is overt takeover of the facility by the host nation. The first threat is addressed by IAEA safeguards, whereas the second is of international concern but is outside the IAEA charter. It will be assumed that the overt takeover issue will remain outside the charter of the IAEA, but elements making the design less attractive for host nation takeover will be addressed by nuclear supplier countries.

Additional assumptions are:

1. The facility is under IAEA safeguards.
2. The only two threats posed by the host nation are overt takeover with abrogation of the IAEA agreement or diversion of material from the safeguarded facility to a facility not under IAEA safeguards.
3. If a nation so desires, it can obtain nuclear weapons capability by independent means.

International Safeguards Goals and Objectives

The threat of covert diversion of material from the facility is countered by IAEA safeguards. The stated objectives(8) of IAEA safeguards are "...the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other nuclear explosive devices or for purposes unknown, and the deterrence of such diversion by the risk of early detection."

The following safeguards design objectives appear to counter the threat of overt takeover and the resultant threat of horizontal proliferation. Both these criteria deal with a decision to obtain nuclear weapons quickly.

- The facility should not contain large quantities of nuclear materials that a nation can readily convert to nuclear weapons.
- The facility should not give the nation the capability for quick conversion of nuclear materials into nuclear weapons.

To counter the threat of vertical proliferation, the following objectives appear to be appropriate:

- The cost of modifying the facility for use in weapons fabrication should be very high.
- Alternatively, it should be more attractive for a nation to build independent facilities for weapons fabrication.

Considerations for Design Criteria for International Safeguards

Under INFCIRC/66, a nation pledges that the materials or facilities submitted for safeguards will be used only for the declared peaceful purposes. Nations that sign and ratify the NPT promise to declare all of their nuclear facilities and to abstain from proliferation. In both cases, the agreement between the country and the Agency requires that each relevant facility be described as to purpose, size, and type of operation. Although the IAEA may treat some of this information as confidential, the result is that the number, location, size, and capacity of every reactor or processing facility under IAEA safeguards become public. This in itself provides every nation with information on the nuclear programs of its potential rivals or adversaries.

The general objective of IAEA safeguards is to provide additional assurance that a pledge to refrain from diversion is honored. In INFCIRC/153 the objective of safeguards is stated as "the timely detection of diversion of significant quantities of nuclear material--and deterrence of diversion by the risk of early detection." The degree of deterrence will depend on a nation's perception of the consequences of being detected, i.e., the reaction of other nations, as well as on the perceived risks of being detected.

Any nation that has volunteered its nuclear facilities for IAEA safeguards presumably has concluded that this move will enhance its national security so long as other nations do likewise. For this reason, it will want the IAEA safeguards applied in other countries to be effective and credible. Consequently, each nation under safeguards should feel obliged to cooperate fully with the IAEA inspections of its facilities. In this respect, the objective of IAEA safeguards could be interpreted as a means to provide credible assurance to other nations that no diversion is taking place.

IAEA inspection is based on material accountancy, "the safeguards measure of fundamental importance, with containment and surveillance as important complimentary measures." The national operators of a nuclear facility are required, in the agreements signed under INFCIRC/66 or 153, to make the necessary measurements, to maintain records of nuclear materials on-hand and being processed, and to make monthly reports to the IAEA. The Agency's material accountancy function is based on the independent verification of the quality and accuracy of the individual facility records and reports. At Agency headquarters, the reports submitted by a nation on the materials at each of its facilities, and the reports on IAEA verification are compared and evaluated.

Agreements pursuant to INFCIRC/66 do not specify just how the Agency inspectors are to verify measurements and reports. The NPT and INFCIRC/153, however, specify that the IAEA is to perform its verification activities at "strategic points," which are to be defined in each Agency-facility agreement (Facility Attachment). These are of two sorts: flow key-measurement points, and additional key measurement points for performing measurements during the periodic physical inventories of stocks on-hand.

The role of containment and surveillance is to ensure that nuclear materials are not diverted around the measurement stations. The Agency accepts the containment features built into a facility, to the extent that these are verifiable. Surveillance measures may depend on the activities of inspectors or may involve technical aids, such as motion detectors or closed-circuit TV. An important technique is the use of seals to indicate that a container, or vault, or light-water power reactor has not been opened since the seal was attached.

In order to fulfill its responsibility, to be able to detect diversion of a "significant quantity of nuclear material" in a "timely" manner, the IAEA has concluded that a "significant quantity" should be related to the amount of nuclear material needed for a nuclear explosive, and that the timeliness of detection should be related to the time that it might take a nation to convert the stolen nuclear material into a form suitable for use in a nuclear weapon. The amounts of high-enriched uranium or plutonium required for a nuclear explosive have been taken from a report prepared for the Secretary General of the United Nations in 1967, i.e., 25 kg of U-235, 8 kg of plutonium, or 8 kg of U-233. The Agency has, somewhat arbitrarily, adopted the values of 25 kg of U-235 contained in uranium enriched to greater than 20%, 75 kg of U-235 contained in uranium with an enrichment of less than 20%, and 8 kg of plutonium of any isotopic composition (but excluding plutonium with more than 80% Pu-238) as safeguards design objectives. However, since these may be difficult to achieve in some cases, the Agency is careful to state that these are not to be considered as immutable requirements.

As will be discussed below, "detection" of the diversion of a target quantity of nuclear material involves a number of nontrivial operations. Measurements made by the operator and measurements made by IAEA inspectors for the purpose of verification will necessarily be subject to some uncertainty. Reporting and clerical errors will need to be corrected. It is necessary to understand the magnitude of all types of measurement uncertainties (for weight, sampling, analytical error, etc.) and to combine them properly for all the measurements made during an accounting period in order to determine the resultant uncertainty for the total quantity. There will always be some difference between the quantity that the running accounts indicate should be on-hand and the amount measured during a physical inventory. If the IAEA confirms that this difference (called the Material Unaccounted For, or MUF) is less than the uncertainty computed for the amount reported, it would normally conclude that no diversion was indicated. If the MUF is larger than the calculated probable error, there would be some reason to conclude that a diversion had occurred. But, unless the MUF was substantially larger than the probable error of measurement, there is some possibility that the discrepancy is itself caused by errors. The Agency cannot simultaneously have a high probability of detecting diversion of a quantity that is comparable to the combined measurement errors (those of the operator and those of the inspectors) and a high degree of assurance that the "detection" is not a mistake (a false-alarm). The Agency cannot afford to make many mistakes.

Finally, the system relies on such measures as containment and surveillance to insure that all nuclear material was measured and reported.

With regard to timeliness of detection, the IAEA has concluded that detection should occur in a very short time (days to weeks) for materials which would require but little processing for conversion into a form suitable for use in a nuclear explosive (e.g., plutonium or high-enriched uranium oxide powder or mixed-oxide pellets), longer times for dilute or highly radioactive materials for which substantially more effort would be required to extract and convert contained plutonium or high-enriched uranium, and still more time (on the order of a year) for natural or low-enriched uranium compounds which would require enrichment or transmutation for a military use. These detection times are shown in Table 4 and are taken directly from an article by G. Hough, et al.(9)

Again, these "timeliness goals" have been adopted as safeguards system design goals and not as safeguards requirements. Under present circumstances, it may be impossible to achieve both the quantity and timeliness goals at some nuclear facilities of major significance. At this time, physical inventories at fuel processing facilities (enrichment, fabrication, reprocessing) are performed at intervals ranging from two months to a year or longer. It would not be possible, then, to detect a diversion of plutonium or high-enriched uranium on the basis of such material balance periods, in a time shorter than the time between physical inventories. At the other extreme, the IAEA design goal is to detect the diversion of one significant quantity in a year. With present, or even with improved, measurement methods, the measurement uncertainties over a year for a reprocessing plant the size of Barnwell would be considerably larger than 8 kg of plutonium.

Table 4

ESTIMATED MATERIAL CONVERSION TIMES

Material Classification	Beginning Material Form	End Process Form	Estimated Conversion Time
1	Pu; HEU*, or U-233 metal	Finished plutonium or uranium metal components	Order of days (7-10)
2	PuO_2, $Pu(NO_3)_4$ or other pure compounds. HEU or U-233 oxide or other pure compounds	Finished plutonium or uranium metal components	
	MOX or other non-irradiated pure mixtures of Pu or U $[(U\text{-}233/U\text{-}235)] \geq 20\%$. Pu, HEU and/or U-233 in scrap or other miscellaneous impure compounds	Finished plutonium or uranium metal components	Order of weeks** (1-3)
3	Pu, HEU or U-233 in irradiated fuels ($\geq 10^5$ Ci/kg HEU or U-233 or Pu)	Finished plutonium or uranium metal components	Order of months (1-3)
4	U containing $<$ 20% U-235 and U-233; thorium	Finished plutonium or uranium metal components	Order of one year

---

* Uranium enriched to 20% or more in the isotope U-235.

** While no single factor is completely responsible for the indicated range of 1-3 weeks for conversion of these plutonium and uranium compounds, the pure compounds will tend to be at the lower end of the range and the mixtures and scrap at the higher end.

In view of these problems, the IAEA is consulting with its member States as to what they believe the qualitative or quantitative goals should be in the future and has requested its members to assist in developing improved safeguards techniques, which should enable it to achieve reasonable goals at future large nuclear processing plants.

Recalling the objective of international safeguards, it is the "timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons...." The single operating criterion for international (more accurately, IAEA) safeguards to be effective is "timely detection of diversion," and it is this operating criterion that needs to be translated into design criteria.

In order to provide for "timely detection of significant quantities," the facility design must provide for 1) accessibility of materials and records to IAEA inspectors; 2) ability to perform rapid inventories on demand; and 3) accommodation of surveillance and containment techniques.

1. The design provision for accessibility of materials and records to IAEA inspectors requires that a) all records be available and auditable on a rapid-recall basis (this mandates an automated data-keeping system, compatible with the IAEA system, and incorporating the capability to cross-check and overcheck input and output data to reduce recording errors); and b) special nuclear material in storage and in process be accounted for (the accountancy requirement can be combined with the quality control requirements to facilitate the sampling procedures of both requirements).

2. The design provision for inventory requirements can be accommodated in the facility design to enable in-process inventories to be taken. Otherwise, the plant would have to be shut down and equipment drained to account for the presence of materials such as plutonium and high-enriched uranium.

3. The design provision for surveillance dictates a high degree of visibility in the areas where SNM is used and stored, at least to the extent surveillance is necessary and to the extent dictated

by the particular surveillance technique to be used. Containment, according to IAEA documents, "takes advantage of existing structural characteristics, such as containers, tanks or pipes to establish the physical integrity of an area or item by preventing the undetected movement of nuclear material or equipment."

Because IAEA safeguards are applied by agreement between the State and the IAEA, these safeguards are not a requirement in the same sense that NRC places requirements on the licensed nuclear industry. This "agreement" relationship between the State and the IAEA dictates consideration should be given to additional factors in the development of IAEA safeguards design criteria. One such factor is of sufficient importance to be listed as an additional consideration:(a)

4. Acceptability to the State having jurisdiction over the safeguarded facility. Unless subsidiary agreements that are mutually acceptable to the State and the IAEA can be negotiated, the safeguards will not be applied. The State is obligated, for example under the NPT, to accept safeguards, but at the same time the IAEA cannot impose safeguards measures except by State consent. Whatever other desirable features a concept may have, the impact on the State and facility must be reasonable.

In conclusion, design criteria to accommodate IAEA safeguards should recognize both the existing IAEA safeguards requirements and IAEA safeguards goals and provide for their implementation. The threat which IAEA safeguards are to deter, i.e., national diversion, will not change. The techniques for deterring diversion through timely detection of such diversion will likely remain the same. Design criteria must make allowance for taking rapid inventories and material flow verifications, surveillance, and containment.

(a) J.M. de Montmollin, Sandia Laboratories, personal communication to J.A. Powers, Teknekron, September 13, 1979.

4.0 FUTURE EFFORTS

Identifying safeguards and nonproliferation considerations is only the first step in a structured design process. It is an essential step, however, because its gives the framework on which a decision-making process is built. The considerations presented here represent the results of a three-day workshop attended by ten individuals. This document presents a summary of the efforts of these individuals and is presented to the safeguards community with the expectation that it will be added to, modified, and changed to reflect the views of a broader group of individuals. Once the review process is completed, it might be reasonable to call the considerations a set of overall design criteria.

Reaching consensus on a set of overall design criteria is fundamental to the design process. Safeguards should not be an add-on; it should be an integral part of the design. Nonproliferation attributes should be treated similarly.

There are two major risks associated with the development of design criteria. First, on some issues it may be impossible to reach consensus. Second, design criteria desired by the public may be unattainable. The first risk can only be resolved by regulatory agencies who have been vested with the authority to decide such issues. The second risk entails a compromise on the part of the general public, one that some segments will not be willing to make. Once again, the ultimate authority for these decisions is vested with regulatory agencies.

While the risks are large, there are also benefits from developing a set of design criteria. First, the criteria provide a design base which is understandable by the general public because they have been involved in its development. Secondly, the criteria set priorities among development activities. Most importantly, design criteria establish the framework for developing a set of acceptable performance criteria. These criteria establish when enough is enough. Without them, layer upon successive layer is added to the system in an endless spiral of ratchets that doesn't cease even after the facility becomes operational.

While it is considered important to obtain a set of overall design criteria before proceeding, subsequent development steps can also be outlined. It is only their content that is in doubt. Figure 2 shows a sequence of interacting tasks which takes the overall safeguards and nonproliferation design criteria, integrates them with process and equipment development in conjunction with activities, and ultimately includes the criteria in the facility design activities. This figure was prepared as part of the FRAD program plan activities.(10) Other criteria, such as earthquake protection, can be added to the design activities much later in the process because established criteria and evaluation techniques already exist.

Tracing through Figure 2, the Safeguards and Nonproliferation Consideration task is shown in the upper left-hand corner of the diagram. This document is a result of that task and the follow-on task titled Safeguards Nonproliferation Design Criteria. The other major activities that structure FRAD come as Fuel Cycle Design Requirements and Refabrication Design Approaches. These are the major inputs that have been used to describe the FRAD program plan. Subsequent activities relating to safeguards and nonproliferation can be divided into four major program areas:

Assessment Methodology Development
Process Modeling
Control and Process Instrumentation Development and Demonstration
Process Equipment Development and Demonstration

Each of these areas has major developmental needs requiring a concerted design effort over a period of several years. None has adequately addressed safeguards and nonproliferation effects. The major needs in each area will be briefly addressed in the following paragraphs.

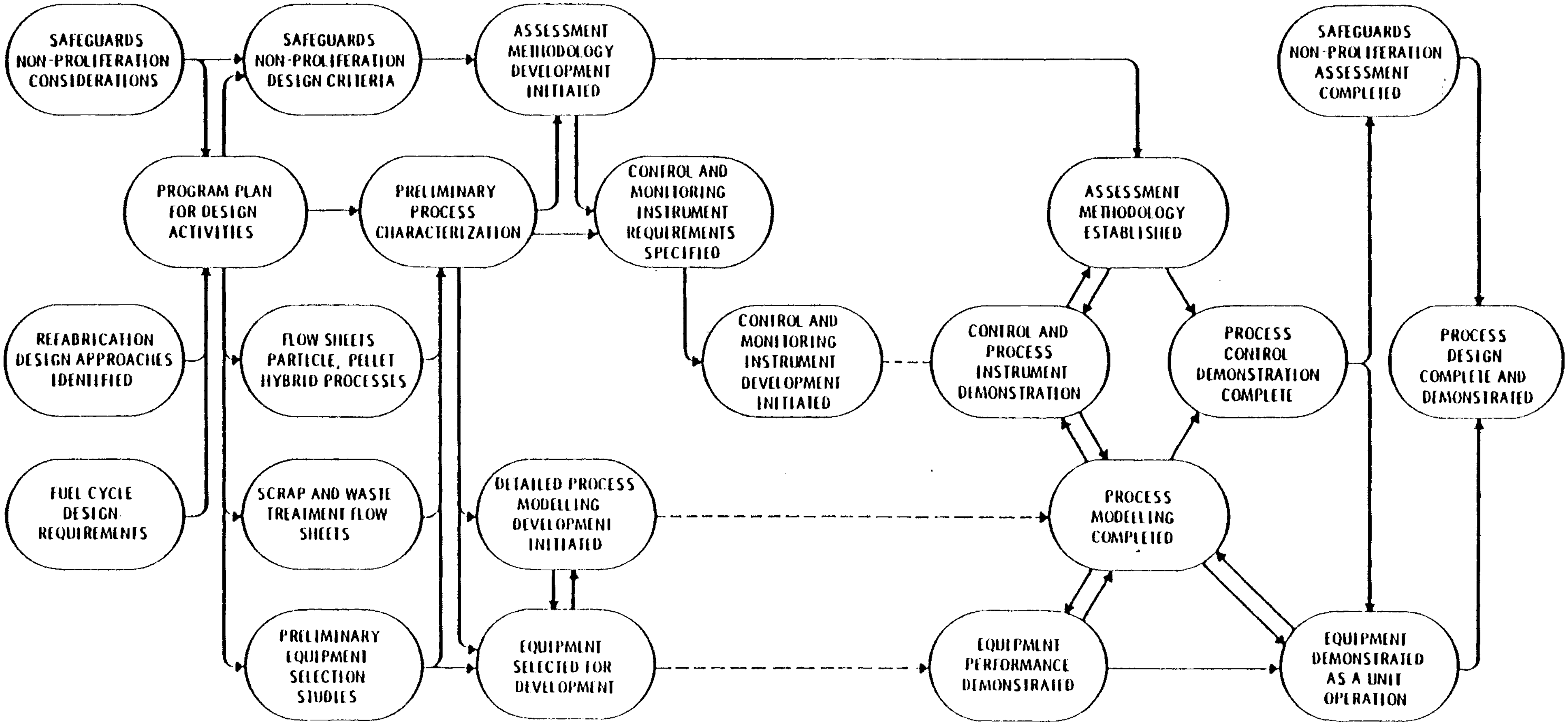

Figure 2. Sequence of Future Design Activities

Assessment Methodology Development

While several studies have developed parts of an overall assessment methodology, the present assessments address only segments of the problem. Accepted methods to evaluate some criteria don't exist because the criteria haven't been formulated. An approach for evaluating proliferation resistance, developed at the workshop, is shown in Appendix A.

The assessment task has a major interface with the Control and Process Instrumentation task, since these instruments provide the basic data for the assessments. The activity requires taking the set of design criteria, establishing measures of performance, and then identifying data and instrument requirements to monitor performance. A key link between these tasks is the process modeling task, since the models can be used to describe preliminary performance characteristics.

The process of establishing methods for measuring performance will identify instrument needs and, subsequently, instrument development requirements. The performance of instruments ties back into the assessment methodology task about the time demonstrations of process control and equipment performance are being performed. The assessment methodology developed via this process is used in making design trade-offs and ultimately becomes an integral part of the process control and monitoring system in the operating plant.

Process Modeling

The modeling of a process begins with conceptual flow sheets and a preliminary set of performance characteristics. This modeling is periodically updated as equipment and process monitoring and control performance data are obtained. Based on the performance data, design trade-offs can be evaluated without requiring an actual demonstration of the equipment configuration. As was the case with the assessment methodology, the process model becomes an integral part of the process control and monitoring system in the operating plant.

Control and Process Instrument Development and Demonstration

The assessment methodology and process modeling tasks identify performance characteristics for control and monitoring of the process. The control and process instrument development and demonstration tasks are multi-year tasks to develop and demonstrate process control and to monitor instrumentation identified for measuring the performance of the operating plant. A demonstration of process control and monitoring equipment performance completes this series of tasks.

Process Equipment Development and Demonstration

The development and demonstration of process equipment is the most costly and time-consuming series of tasks that must be performed. However, they are preceded by a series of studies that specify performance requirements. As equipment development progresses, information on performance characteristics is collected and incorporated in process modeling tasks. Use in the assessment methodology and instrument development tasks can also occur. At the completion of equipment development activities, it will probably be necessary to show the equipment operating characteristics as an integrated process. This process demonstration task will also show that the design criteria established at the start of the program will be attained in an operating facility.

Summary

The preceding paragraphs have attempted to identify the sequence of design activities that must be followed to develop a design that meets a set of performance criteria. While other planning efforts might result in a different set of names for the design activities, the overall process must proceed along the guidelines established above. The importance of establishing design criteria is clearly shown.

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APPENDIX A

Criteria for Evaluating Proliferation Resistance

As discussed in the Future Efforts section, the next step after developing a set of design criteria is to develop a methodology for evaluating whether a given design is capable of attaining the program goals and objectives. The following approach was formulated in the workshop and is presented as a possible approach to evaluating the proliferation resistance of a design.

The discussion considered three issues:

1. The ease with which a nation could obtain nuclear weapons given the overt takeover of the facility
2. The long-term usefulness of the facility for weapons fabrication given the overt takeover of the facility
3. The likelihood that a nation could divert sufficient quantities of nuclear material from a facility under IAEA safeguards and not be detected

The workshop participants felt the first and third issues were more important, and an attempt was made to use the same methodology for both.

Initially, two terms were defined:

> Proliferation is the manufacture or acquisition of nuclear weapons or other nuclear explosive devices by countries which do not now possess them.
>
> Proliferation Resistance is defined in terms of the probability of proliferation occurring. It was felt useful to define the probability of proliferation as the product of two components: motivation X capability. Motivation is thought to be largely nontechnical, whereas capability is a purely technical issue.

Motivation would address issues such as national sovereignty; capability addresses technical requirements such as knowledge, skill, material, and effort. Whereas it is very difficult to measure motivation, the technical elements appear to have distinct measures.

It is possible to act against both components in the definition of proliferation resistance. Technical design features can be incorporated into the facility to make it more difficult to obtain a weapon. The possibility of sanctions imposed by other nations may reduce a nation's motivation to become a weapons state. Thus, it is possible to act on both terms in the proliferation-resistance equation.

In equation form, the issues that give a nation the motivation to obtain nuclear weapons could be classed as incentives. The issues that lessen the motivation could be classed as deterrents. Then motivation becomes the balance between incentives and deterrent action. Two counteracting elements also act on capability. One is the resources needed to obtain a nuclear weapon. This is countered by technical barriers which would include obtaining weapons design information. It would also include acquiring equipment, skills, and materials needed in nuclear weapons fabrication.

To characterize technical deterrence, a three-dimensional matrix was developed. It is shown in Figure A-1. Two axes are inputs. On one are placed the equipment, skills, and materials needed by the proliferating nation. On the other axis are placed the terms "accessibility" and "convertibility." The term "accessibility" addresses the amount of equipment, skills, and material made available to the state by siting a facility in a nonweapons state. The term "convertibility" addresses the usefulness of the equipment, skills, and material in weapons fabrication. The measures of resistance, then, are the time, effort, money, and risk of detection a nation must take to establish a nuclear capability.

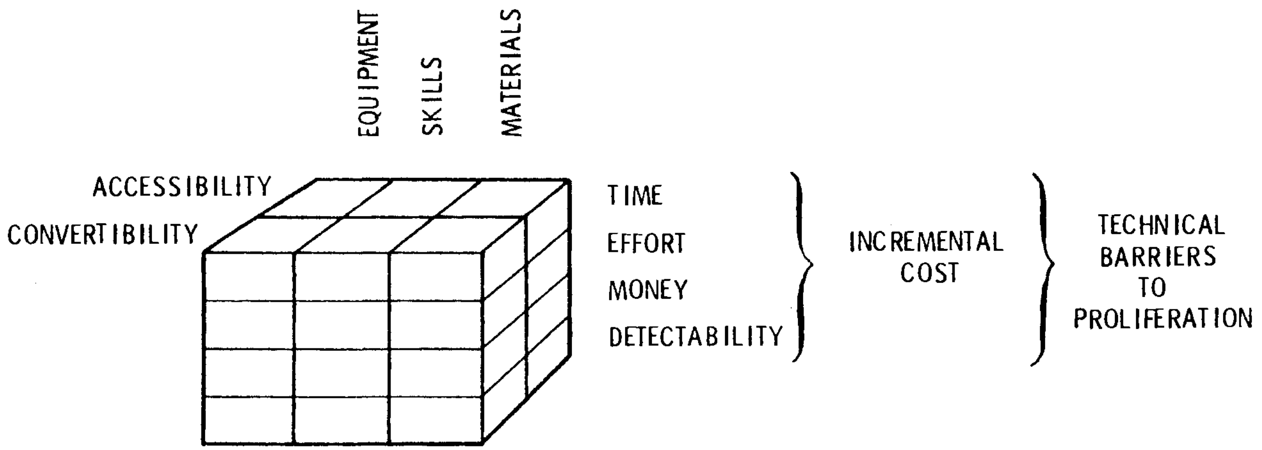

FIGURE A-1. Proliferation-Resistance Evaluation Matrix

To show how the matrix would be used, consider the time dimension for locating a refabrication facility in a nonweapons state. Equipment, skills, and material needed for a weapons program would be compared against the equipment, skills, and material present in the proposed facility. If, for example, the only element of concern was material, the questions of availability and convertibility would be addressed. How long it would take to obtain the material would be put in the matrix at the location depicted by the labels "Time," "Materials," and "Accessibility." The next question addressed would be the length of time required to convert the material into a weapons-usable form. This time would be placed in the matrix at the location depicted by the labels "Time," "Materials," and "Convertibility." This would be done assuming a nation desired to obtain quantities of material of safeguards significance. Going one step further, if one uses the detectability goal of the IAEA as an additional constraint, and the total time to obtain access to and convert the material was greater than the IAEA timeliness goal, the proliferation resistance of the design might be deemed acceptable.

In developing this matrix, it is recognized that a nation has two alternatives. One is to attempt to divert material and risk detection by the IAEA. Alternately, the nation may abrogate the IAEA treaty, thereby setting the risk of detection at one, and then developing its nuclear capability in the most expeditious manner. It was felt that the methodology shown in Figure A-1 could handle both cases.

Case (1) The Nation Abrogates IAEA Agreements

The workshop participants felt that this case was the most serious concern because the nation could invest large quantities of money and effort to establish its nuclear capability as soon as possible, thereby minimizing the time it would be most vulnerable to sanctions. For this case, the matrix could be filled out as shown in Figure A-2. The term Q(t) is the total quantity of weapons material desired by the nation at some time denoted as "t." There is

Figure A-2

PROLIFERATION MATRIX FOR CASE WHERE NATION ABROGATES THE IAEA TREATY

	TIME	
	Accessibility	Convertibility
Material	Time to acquire and move Q(t) to where it will be converted	Time required to process Q(t) into metal at. weapons components
Equipment	Time to acquire or deploy equipment	Time to modify for use

	EFFORT & MONEY	
	Accessibility	Convertibility
Material	Time to acquire and move Q(t) to where it will be converted	Time required to process Q(t) into metal at. weapons components
Equipment	Time to acquire or deploy equipment	Time to modify for use

probably an optimum Q(t) which is most cost effective. Alternately, for short times, it would be desirable if the effort or money required was beyond the capability of the nation. Using the same technique, a curve could be generated for the nation embarking on a clandestine weapons program. A design that gives a curve with better performance than the clandestine curve would be considered highly proliferation-resistant.

In the above evaluation, detectability is not of concern because the nation has told the world it is going nuclear by abrogating the treaty. Case 2 looks at the alternative where the nation risks detection by the IAEA.

Case (2)   Nation Diverts Material from Facility under IAEA Agreements

The previous case only considered the time, effort, and money required for a nation to go nuclear. The risk of detection didn't have to be considered. While the time, effort, and money curves may change when going from case 1 to 2, the same principles will apply. Now the nation must carefully select its actions to minimize the risk of detection by the IAEA.

Figure A-3 shows an approach for evaluating detectability. The word "visibility" is employed to describe the likelihood an activity will be detected. Table A-1 shows some measures of visibility which were developed by workshop participants.

In addressing the issue of detectability, consideration is given to both timeliness and likelihood of detection. As discussed in the workshop, it is not sufficient to evaluate timeliness or detectability by just looking at the alarm system. Timeliness must consider the time to detect plus the time to respond. The probability of detection must consider the likelihood that a signal will sound and be properly resolved. A signal must not only be timely, it must also be unambiguous. At the workshop, it was felt that a nation could employ many tactics to delay the response or even cancel all response to a positive detection of diversion.

Figure A-3

ADDITIONAL PROLIFERATION MATRIX ELEMENT FOR CASE WHERE PROLIFERATION OCCURS WHILE FACILITY IS UNDER IAEA SAFEGUARDS

	DETECTABILITY	
	Accessibility	Convertibility
Material	Visibility of process of gaining access to material	Visibility of activities req'd to process Q(t) into at. weapons component
Equipment	Visibility to acquire or deploy equipment	Visibility to modify for use

Table A-1.

Measures of Visibility

- Measurability
- Inspectability
- Redundancy
- Opportunity for Observation, Duration of Visibility
- Follow-up (Investigation - Remeasurement)
- Containment
- Process Controls
- Localization of Losses
- Minimization of Diversion Points

Examples of ambiguity include:

1. Offering plausible explanations such as: the material is really present, but it is present as holdup in an unmeasurable location.
2. Initiating an ineffective investigation which takes an inordinate period of time, thereby rendering the initial timeliness of the diversion signal ineffective.
3. Initiating bureaucratic delays.
4. Degrading measurement quality thereby making the diversion signal less statistically certain.
5. Carrying out non-routine transfers that effectively complicate the accounting records and thereby cover up the diversion.

Because these sources of ambiguity can render a design ineffective, any evaluation of detectability should include an evaluation of how the detection signals might be made ambiguous.

Workshop participants felt that the evaluation criteria summarized in Figure A-1 might be a useful tool for evaluating the relative proliferation resistance of various design alternatives. These criteria appear to be general enough to apply to any fuel cycle facility. This means it would be possible to determine the relative proliferation resistance of very diverse fuel processing facility designs.

It was pointed out in the workshop that design goals have to be established. Granted these goals are but one point on the power curve relating probability of detection to quantity missing, but the IAEA has established some long-term design goals which are not immediately achievable. By setting such goals, research directed at their attainment can be given high priority. For these reasons, nonproliferation goals also need to be established.

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