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GENERIC PHYSICAL PROTECTION LOGIC TREES

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ABSTRACT

Generic physical protection logic trees, designed for application to nuclear facilities and materials, are presented together with a method of qualitative evaluation of the trees for design and analysis of physical protection systems. Information must be gathered or assumptions made about the threat spectrum and site characteristics. The objectives of physical protection are used to define one or more defense zones where adversaries interact with the physical protection system. Logic trees that are needed to describe the possible scenarios within a defense zone are selected. Each tree is edited to accurately reflect the characteristics of the site. For design or analysis, elements of a postulated or existing physical protection system are tagged to the primary events of the logic tree. The likelihood of adversary success in overcoming these elements is evaluated on a binary, yes/no basis. The effect of these evaluations is propagated through the logic of each tree to determine whether the adversary is likely to accomplish the end event of the tree. To be effective, the physical protection system must be highly likely to overcome the adversary before he accomplishes his objective using any combination of tactics: deceit, force, or stealth. The evaluation must be conducted for all significant states of the site. Deficiencies uncovered become inputs to redesign and further analysis, closing the loop on the design/analysis cycle.

Qualitative evaluation using logic trees is especially suitable as an introductory technique. The effectiveness of the total physical protection system is analyzed. The technique is general, not specialized. Any sort of interaction between adversary and physical protection system can be analyzed by qualitative techniques, though with less detail than is provided by quantitative techniques. Qualitative evaluation can be performed quickly through use of logic trees and is accomplished entirely by the activity of the analyst. Logic trees can be used in preliminary screening to select attack scenarios for quantitative analysis.

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GENERIC PHYSICAL PROTECTION LOGIC TREES

1. INTRODUCTION

This report presents 13 generic physical protection logic trees and discusses their qualitative application to nuclear facilities and materials for both system evaluation and design. The text extends portions of the "International Training Course on Physical Protection of Nuclear Facilities and Materials" (sponsored by the International Atomic Energy Agency and the US/DOE). The generic trees are the direct descendants of a set developed in 1976 for analysis of nuclear facilities of the Department of Energy. Both trees and application methodology have evolved toward greater simplicity, speed of use, and flexibility to match the unique needs of a variety of applications. Even so, these are relative advantages over alternative methods. (Of course, if depth of detail for one particular scenario or extensive quantitative results are needed, these can be relative disadvantages.) In absolute terms, a full qualitative analysis of a realistic site can be complex and extensive. For this reason, it has been necessary to illustrate the applications guidelines with simple, abbreviated examples. These, however, cover the essential techniques and point the way to carry out a complete design and analysis of a physical protection system (PPS).

There are three major subdivisions of the text, supplemented by appendices that contain the generic logic trees in both complete and abridged form. "Introduction to Logic Symbols" defines the symbols used in logic trees. The AND gate, OR gate, and the transfer operation are explained. The three primary events and the end event are defined. The naming of events is explained.

"Introduction to Generic Logic Trees" explains why qualitative evaluation of logic trees is used. Physical protection terminology is defined. Topics discussed are the concept of a defense zone, the relationships between the zone and physical protection system functions, the types of generic logic trees, how to select generic logic trees to design or evaluate physical protection in a zone, the method of reading a logic tree, and the common properties of BOUNDARY trees. Each of the three trees, STEALTH-BOUNDARY, FORCE-BOUNDARY, and DECEIT-BOUNDARY is presented in abridged form and explained.

"System Design/Analysis Technique" discusses qualitative evaluation of physical protection systems. The qualitative evaluation technique employs generic logic trees and the zone concept. Suggested methods should make the design and analysis cycle efficient. Topics discussed are the design/analysis cycle, analysis technique, information required about the adversary and the site, examples of applying the analysis technique (using only the tree, STEALTH-BOUNDARY), fitting a generic logic tree to a particular facility, describing or designing the PPS, and evaluating a PPS.

2. INTRODUCTION TO LOGIC SYMBOLS

The logic tree is an important tool used to evaluate the effectiveness of physical protection of nuclear facilities and materials. The purpose of the logic tree is to describe all of the ways that an adversary can achieve his objective by defeating elements of a physical protection system. An event is an act that an adversary must perform against a physical protection system to achieve his objective. In a logic tree, these events, which are represented by special symbols, are logically connected. In order to use logic trees, it is necessary to understand the individual parts of the tree and the symbols used in the composition of the trees. Figure 1 illustrates the symbols that are used for logic trees.

Figure 1. Logic Tree Showing Symbols Used

Each event has a written description which is contained in a rectangular symbol in the logic tree diagram. The description of the topmost event in Figure 1 is "Defeat Perimeter Boundary Undetected." A smaller rectangle, which is placed immediately under the description, is used to provide the event name. For example, S is the name of the topmost event shown in Figure 1. Event names are usually brief and are formed from combinations of letters and numbers. Event names are used in the computer processing of logic trees.

LOGIC GATES AND SYMBOLS

The symbol which appears below the event name is used to designate either how that event is logically related to other events or how well the causes of the event are known. Two kinds of logic gates, the AND gate and the OR gate, are used in the logic trees. Gates must have at least two inputs and may or may not have an output. Inputs enter the bottom of the gate; outputs exit the top of the description rectangle above the gate. If a gate does not input to another gate, it generates an end event. The objective of the adversary is always the end event of a logic tree. The logic trees which are described in this module each have only one end event, the topmost event of the tree. In Figure 1, S (Defeat Perimeter Boundary Undetected) is the end event. The shape of the AND gate is a round arch with a flat bottom (see Figure 2). For an adversary to accomplish the event described above the AND gate, the adversary must accomplish all of the events which input into the AND gate. If the physical protection system can prevent any one of the input events, the adversary is prevented from accomplishing the event described above the AND gate. For example, suppose event E-AND is generated by an AND gate whose inputs are events 1-1, 1-2, and 1-3. Event E-AND will occur if and only if event 1-1 and event 1-2 and event 1-3 all occur. Figure 2 summarizes the properties of the AND gate.

ADVERSARY MUST ACCOMPLISH ALL EVENTS INPUTTING TO THE GATE.
PREVENTING ANY ONE INPUT EVENT DEFEATS THE ADVERSARY.

EVENT E-AND OCCURS IF EVENT 1-1 AND EVENT 1-2 AND EVENT 1-3 OCCUR.

Figure 2. Example of an AND Gate

For the logic tree shown in Figure 1, event S will occur only if event SI-1 (Avoid Personnel Undetected), event SI-2 (Penetrate Boundary Undetected), and event SI-3 (Avoid or Confront Patrol Guards Undetected) all occur. The adversary can penetrate a boundary without being detected only by accomplishing all three of the tasks associated with events SI-1, SI-2, and SI-3; i.e., (1) by avoiding accidental detection by personnel, (2) by physically surmounting the boundary undetected by

elements of the physical protection system which are designed to detect an intrusion, and (3) by avoiding detection by patrol guards.

The shape of the OR gate is a pointed arch with a curved bottom (see Figure 3). For an adversary to accomplish the event described above the OR gate, the adversary need only accomplish any one (or more) of the events which input to the OR gate. The physical protection system must prevent all of the input events in order to prevent the adversary from accomplishing the event described above the OR gate. For example, suppose event E-OR is defined by an OR gate whose inputs are events 1-1, 1-2, and 1-3. Event E-OR occurs if any one of events 1-1, 1-2, or 1-3 occurs. Figure 3 summarizes the properties of the OR gate. For the logic tree shown in Figure 1, event S1-2 (Penetrate Boundary Undetected) will occur if either event S2-1 (Defeat Boundary Barriers Undetected) or event S2-2 (Defeat Boundary Emergency Exits Undetected) occurs. Thus, the adversary can penetrate a boundary without being detected in either of two ways: (1) by undetected passage through an emergency exit or (2) by undetected penetration of the barriers which constitute the boundary.

ADVERSARY HAS ALTERNATIVE WAYS TO ACHIEVE SUCCESS.
ALL EVENTS INPUT TO THE GATE MUST BE PREVENTED.

EVENT E-OR OCCURS IF EVENT E-1 OR EVENT E-2 OR EVENT E-3 OCCUR

Figure 3. Example of an OR Gate

EVENTS

Events which have both inputs and outputs are called intermediate events. In Figure 1 there is only one intermediate event, S1-2.

Events which do not have an input are called primary events; they represent the causes of the end event. A logic tree is a logical combination of primary events. Three types of primary events are distinguished by the symbol which appears immediately below the name of the primary event: the basic event, the undeveloped event, and the developed event.

The basic event is symbolized by a circle. A basic event can be understood and evaluated qualitatively or quantitatively, depending on the purpose of the analysis, without further developing the event into causes or cases. In Figure 1, event S1-1 (Avoid Personnel Undetected) is the only basic event. Events that describe unlikely accidental circumstances by which an adversary could avoid detection by non-security personnel are usually excluded from the logic tree. S1-1 can be evaluated. It is judged that, except for an accident, an adversary could easily avoid personnel undetected. S1-1 need not be developed further since an analyst is required to evaluate only one possibility: Can an adversary avoid facility personnel without being detected? Event S1-1 can be contrasted with event S1-3 which is not a basic event. For event S1-3, the analyst is asked to evaluate whether the adversary can avoid or confront patrol guards without being detected.

The undeveloped event is symbolized by a diamond. An undeveloped event is an event whose causes are insufficiently understood to be included in the logic tree. It is not possible to say whether, given more information, an undeveloped event would be developed or treated as a basic event. The conclusions drawn from the analysis of a tree which contains an undeveloped event are tentative and subject to revision. In Figure 1, event S2-2 (Defeat Boundary Emergency Exits Undetected) is the only undeveloped event. This event is considered an undeveloped event since all of the various kinds of emergency exits have not been studied. Also, there is no information by which the logic tree could show how all of the types of emergency exits could be defeated without the adversary's being detected.

The developed event is symbolized by two concentric diamonds. The causes of a developed event have been shown in another logic tree* or elsewhere on the same logic tree. The developed event is used as a space-saving convenience. For example, a full logic tree might be inconveniently large. To become familiar with the type of information contained in the tree, it may be sufficient to examine the uppermost parts of the tree. Expendable events could be deleted from the tree and logic gates no longer having inputs would be replaced by developed events. The resultant tree would be simpler than the original tree, which could be referred to for more development as necessary.

Another example is shown in Figure 4. Assume that two events on the same tree have virtually the same development, differing only in some detail of event descriptions. The development can be shown in detail for one event. The other event can be made a developed event with a comment added that tells where to find the appropriate development. The topmost tree in Figure 4 shows similar developments for events S1-1 (Avoid or Confront Personnel) and S1-3 (Avoid or Confront Guards). Both developments consist of two basic events as inputs to an OR gate. Events S2-1 and S2-3 are similar (Avoid Personnel versus Avoid Guards). Events S2-2 and S2-4 are similar (Confront Personnel versus Confront Guards). Because of these similarities, it is possible to draw the equivalent tree shown at the bottom of Figure 4. The

*In the other logic tree, the event would be generated by a logic gate. It would have a "development" consisting of a subtree generated from primary events through a network of logic gates. It would not be a "developed" primary event.

Figure 4. The Developed Event

full development of event S1-1 is retained, but S1-3 has been made a developed event with this comment added, "Logic Similar to S1-1." Seeing this, the analyst looks at the development of S1-1 and mentally substitutes "Guards" for "Personnel" as he reads the event descriptions. The reader can find a nontrivial application of this technique on the complete logic tree FORCE-BOUNDARY. Developed events F3-30 and F3-40 both have "Logic Similar to F3-20." The development of F3-20, which thus appears once rather than three times, consists of 16 events and 7 logic gates.

TRANSFER OPERATIONS

The transfer operation is represented by an upright triangle. Since many logic trees, as they are developed, expand greatly from left to right across a page, it might be necessary to disconnect the development of an event and place it at a more convenient position on the page or on another page. To relate the event and its development, since they are not connected by a line, the transfer symbol is used. An example of the transfer symbol is shown in Figure 5. A tree is shown on the left that contains no transfer symbol. Its equivalent, using the transfer symbol, is shown on the right as a tree in two seemingly unconnected parts. In the righthand tree, the development of event 1-2 is transferred so that it is centered

Figure 5. Example of Transfer Operations

directly below event X. Note that event 1-2 is shown twice: once in the tree whose development is truncated by the transfer and once at the top of the subtree that develops event 1-2. In general, an event may occur at several places in a logic tree, and the common development of that event may be transferred. The development will appear only once on the page. The X which appears below the transfer symbol and to the left of event 1-2 is the name of the event for which event 1-2 is an input. In general, there will be a list of every event to which the transferred event is an input.

EVENT NAMES

To assist in the location of events on logic trees that appear in this module, a convention for event names has been adopted. The end event can be arbitrarily named; it may have a mnemonic name suggesting the purpose of its development. All other event names have at least two numerical parts separated by a hyphen. These may be preceded by one or two alphabetic characters. The first optional alphabetic character denotes the tactics for which the tree is developed: D-deceit, F-force, or S-stealth. The second optional alphabetic character, X, denotes that no similar event occurs on the force tree which has a similar end event. This helps the reader to find quickly the similarities and dissimilarities among, for example, all logic trees for crossing a boundary. The number to the left of the hyphen is the row in which the event appears. Rows are numbered in increasing order from the top to the bottom of the tree. The row immediately below the end event is row number one. The number to the right of the hyphen denotes the relative position of the event in its row. These numbers need not be consecutively assigned. It is only necessary that the position number of any event be higher than the position number of the event to its immediate left, and lower than the position number of the event to its immediate right.

For example, find event S2-3 in the topmost tree of Figure 4. The letter S which begins the event name indicates that the tree deals with stealth tactics. The absence of an X following the S indicates that if there is a tree for using force tactics to achieve a similar end event, there is an event on the force tree similar to event S2-3. (In this case, no such force tree exists; the tree S is an isolated, artificial example.) The remainder, 2-3, of the event name indicates that the event will be found in the second row of events below the end event. In that row, read from left to right through increasing position numbers until 3 is reached and event S2-3 has been found. The leftmost event in row 2 has position number 1, the next event to the right has position number 2, and finally the event to its right has position number 3.

If part of the logic tree is transferred, rows in the transferred development are numbered consecutively from the row number of the transferred event. Relative position numbers are sometimes assigned as if the development had not been transferred.

For example, find event S5-60 in the complete generic logic tree, STEALTH-BOUNDARY. Row 5 in the main part of the tree ends with event SX5-30. This is evidence that S5-60 lies within a transferred development. It is quickly seen that

there is only one transferred development for STEALTH-BOUNDARY. S5-60 will be found in the second row below transferred event S3-20. The leftmost position number in transferred row 5 is 40 (event S5-40). So, event S5-60 lies farther to the right and can quickly be found.

3. INTRODUCTION TO GENERIC LOGIC TREES

Logic trees may be used by managers, designers, and analysts to plan and evaluate the physical protection of nuclear facilities and materials. Effectiveness evaluation of physical protection systems requires knowing which possible actions by the adversary must be opposed and which actions can be ignored. Logic trees are a tool for effectiveness evaluations. A qualitative estimate of the effectiveness of a physical protection system and a list of physical protection weaknesses can be obtained through the use of logic trees. Qualitative analysis answers the question, "How effective is the physical protection system?" with either of two responses: "The system is not effective," or "The system is not to be effective." This information can be used to establish the need for further action, together with cost data, to accept or reject system designs.

The topics included in this introduction to logic trees are:

1. Why qualitative evaluation with logic trees is used,
2. Definitions of terminology,
3. The defense zone,
4. Physical protection system functions and the zone,
5. Types of logic trees,
6. Selection of logic trees to analyze a zone, and
7. Reading logic trees.

The method of constructing logic trees is not explained. The necessary information is supplied with this text or as an appendix.

The technique of qualitative analysis using logic trees is illustrated with an example of a nuclear power generating station which requires protection against sabotage of its vital components by outsiders. The technique and the logic trees that are provided have been applied to other parts of the fuel cycle and to facilities which have theft of nuclear materials as their objective.

Two important preparatory steps for qualitative analysis using logic trees are outside the scope of this report. First, targets for sabotage must be identified by vital area location analysis. Second, a threat analysis must be made to establish a spectrum of threats against which the power station requires protection. This information will be used as it is needed.

WHY QUALITATIVE EVALUATION OF LOGIC TREES IS USED

Several techniques for analyzing physical protection systems have been developed. For qualitative evaluation using logic trees is especially suited to the preliminary technique. The effectiveness of the total physical protection system is analyzed. The technique is general, not specialized. Any sort of interaction

between adversary and physical protection system can be analyzed by qualitative techniques, though with less detail than is provided by quantitative techniques. Some other techniques have relatively limited applications, being most useful in the study of particular tactics or objectives of attack.

Qualitative evaluation can be performed quickly through the use of logic trees. This report contains all the specialized material needed for this qualitative analytic technique.

Qualitative analysis of logic trees is accomplished entirely by the activity of the analyst. He is required to think about the interactions between the physical protection system and the adversary. He must be more than a mere collector of the data that is input to a computer. In addition, it is not necessary to spend time to learn the capabilities and limitations of computerized models so that simulation results can be correctly understood. Finally, if the analyst finds that he wishes to use another technique to obtain quantitative results or to study a special situation in greater depth, logic trees can be used in preliminary screening to select attack scenarios for quantitative analysis.

DEFINITIONS OF TERMINOLOGY

There are several words that are frequently used in the discussion of logic trees and their applications.* These words, listed alphabetically, and their definitions follow:

- Adversary -- An adversary is an individual or group of individuals who attempts theft of special nuclear materials or radiological sabotage.
- Communication -- Communication is the function of transmitting or interchanging information, in particular, the signals or messages used to summon protective force personnel who are intended to neutralize the adversary.
- Deceit -- Deceit is the tactic by which an adversary misleads elements of the physical protection system.
- Delay -- Delay is the function of impeding an adversary's progress.
- Detection -- Detection is the function of determining that an unauthorized action is occurring or has occurred. Detection includes sensing of the unauthorized action, communication of an alarm to a control center, and assessment of the alarm.
- Elements -- A physical protection system is a composite entity, and elements are its distinct parts. Physical protection elements have the same name as the physical protection functions which they perform. (See Table 1 for the list of functions and examples of the elements which implement them.) Elements are sometimes called features.
- Force -- Force is the tactic by which an adversary commits overt aggressive actions in order to overcome elements of the physical protection system; the adversary expects to be detected and is prepared to defend against the response.

*See Chapter 2, "Introduction to Logic Symbols," for logic symbol terminology.

Table 1
Physical Protection System Elements and Functions

Function	Example Elements
Detection	
a. Sensor	Fence disturbance sensor Identity check Metal detector Microwave
b. Alarm/display	Television Warning lights/sounds
c. Assessment (real time)	Guard Television
d. Track	Guard in a tower Radar
Delay	Barrier Distance of travel
Communication	Radio Telephone
Response	Guards Local law enforcement (police)

- Functions -- The functions of a physical protection system comprise the group of related actions which together make up the performance of the physical protection system; the functions are detection, delay, communication, and response (See Table 1).
- Insider -- An insider is a person authorized to enter a protected area or a vital area; insiders include employees, contractors, service personnel, and visitors.
- Outsider -- An outsider is a person who is not authorized to enter a protected area.
- Positive Measures -- Positive measures are physical protection elements that have predictable levels of performance for the purpose of preventing the completion of one or more events. Positive measures will not deteriorate abruptly or unpredictably should the severity of the attack be increased by a small amount. There are four methods of implementing or recognizing positive measures in a facility design.
 1. Implement a function with at least two elements so that loss of one element will not cause complete loss of the function,
 2. Select an element to block as many kinds of attack as possible,
 3. Use elements which have complementary strengths together. (For example, a microwave intrusion sensor and a seismic intrusion sensor have complementary strengths. The microwave device can sense an intrusion made using a bridge or ramp to isolate the intruder from the seismic sensor. The seismic device can sense an adversary who is crawling on the ground to avoid the microwave beam which is aimed high to avoid false alarms.)
 4. Simple redundancy can be used for reliability. (The use of two seismic intrusion sensors is an example of simple redundancy.)
- Response -- Response is the function of reacting to the detection of an unauthorized act to prevent adversary success.

- **Stealth** -- Stealth is the tactic by which an adversary attempts to avoid or inactivate elements of the physical protection system; the adversary seeks to prevent detection.
- **Tactics** -- Tactics are the methods used by the adversary to achieve his objectives. (See also Deceit, Force, and Stealth.)
- **Targets** -- Targets are the item or items whose theft or sabotage is the adversary's objective.

THE DEFENSE ZONE

A defense zone is a space which surrounds but is not necessarily occupied by one or more targets and within which any attack is first detected and ultimately terminated by the physical protection system before an adversary can accomplish his goal. The initial boundary of a zone is the envelope of first potential detection of the adversary. The final boundary of a zone is the envelope of last potential termination of the adversary's attack.

A zone of defense surrounding a site may be visualized as a shell that surrounds and protects the targets. The shell may be thin or thick (the thickness need not be uniform) depending on the space needed to terminate an attack. The zone extends into the air above the site to detect attacks mounted from the air. The zone also extends underground beneath the site to detect tunnel attacks.

An attack by outsiders may require a zone as far removed from the targets as possible. An attack by insiders may require more than one zone very close to the targets, perhaps coinciding with the targets themselves.

PHYSICAL PROTECTION SYSTEM FUNCTIONS AND THE ZONE

Detection

The zone begins with a detection boundary because the physical protection system cannot begin to oppose an attack until the attack has been detected. Detection might be desired within the zone as well as at a boundary to provide information on the location of the attackers until they are intercepted by a response force. Detection must occur within the zone, but some detection elements may not be located in the zone. An example is monostatic radar which can detect at a distance, and which need not be installed within the zone in order to participate in the detection of intruders within the zone. Outsiders should be detected at the outer boundary of the zone. Some tactics require that detection elements should also operate within the zone. Outsiders attacking by deceit or stealth might not be detected at the outer boundary of the zone, depending on the effectiveness of the detection elements and the adversary's skill.

Delay

Delay must follow detection and occur within the zone. To provide for alarm assessment, attackers must be prevented from moving too quickly away from the place where they caused an alarm. A barrier is necessary to provide this delay.

The time after detection required by the attackers to reach their target must be at least as long as the time required for the physical protection system (1) to communicate with a response force, (2) to mobilize, transport, and deploy the response force, and (3) to intercept and halt the progress of the attackers. One or more barriers may be necessary to slow the attackers sufficiently to give the physical protection system time to respond effectively.*

Communication

Communication is the function which unites all the physical protection elements into a system. Sensors communicate with alarms or displays. The control center communicates with patrol guards, guards in observation posts, and other response forces. The response force has internal communications. Control signals may be communicated to lights, gates, television cameras, etc. The communication network need not lie entirely within the zone. Communication reliability must be very high.

Response

Response is the function of intercepting the attackers and halting their progress before their goal is achieved. The response element (response force) may be stationed inside or outside the zone, but the response force must carry out its function within the zone.

TYPES OF GENERIC LOGIC TREES

Thirteen logic trees are available for applying the evaluation technique described in this section. All of these trees have one characteristic in common: they are all generic; therefore, each logic tree can be applied to any site. The manner in which the generic logic trees are applied to a site is the subject of Chapter 5, "System Design/Analysis Technique." For the present, it is necessary only to note that no more than 13 trees are needed for qualitative analysis of any site.

The generality of these logic trees implies not only their applicability to virtually any nuclear site but also the kind of unspecific event descriptions that they require: "Default entrances -- gate, portal, or building -- undetected." To require more specific elements of a gate or portal and to perform similar enumerations for other events would make the logic trees excessively large and unwieldy. Such generality in the technology of physical protection systems could rapidly render an exhaustively developed tree obsolete. If general event descriptions are used, the analyst is relied upon to know the state of physical protection technology and need to alter the generic logic trees should rarely arise and the magnitude of the task is kept relatively small.

The 13 trees cover 5 kinds of actions that an adversary may perform. For each kind of action is developed on a set of generic logic trees. In each set, there is one tree for each adversary tactic by which the action can be accomplished. A complete list of generic logic trees is given in Table 2.

*See the Barrier Technology Handbook, SAND77-0777, for a description of the effectiveness of various barriers against attack.

Table 2
Generic Logic Trees

<u>Name</u> <u>(Tactic-Application)</u>	<u>Kind of Action Developed</u>
FORCE-BOUNDARY STEALTH-BOUNDARY DECEIT-BOUNDARY	Penetrate protected boundary
FORCE-AREA STEALTH-AREA DECEIT-AREA	Travel across protected area
FORCE-BUILDING STEALTH-BUILDING	Enter building ^a
FORCE-ACQUIRE SNM ^b STEALTH-ACQUIRE SNM DECEIT-ACQUIRE SNM	Acquire special nuclear materials
FORCE-RELEASE STEALTH-RELEASE	Cause a release of special nuclear materials ^c

^aTo enter a building by deceit, use the DECEIT-BOUNDARY tree.

^bSNM--Special nuclear materials.

^cNo known method causes a release of special nuclear materials by deceit.

The five kinds of actions are (1) penetrate a protected boundary, (2) travel across a protected area, (3) enter a building, (4) acquire special nuclear materials, and (5) cause a release of special nuclear materials. Each action, with two exceptions, can be accomplished by the use of deceit, force, or stealth. The exceptions involve deceit. The tree DECEIT-BOUNDARY satisfactorily describes how an adversary might enter a building by deceit; therefore, no DECEIT-BUILDING tree exists. No method has been found to cause a release of special nuclear materials by deceit; therefore, no DECEIT-RELEASE tree exists. Attacks resulting in a release of special nuclear materials must be analyzed with either the FORCE-RELEASE tree or the STEALTH-RELEASE tree.

SELECTION OF LOGIC TREES FOR ZONE ANALYSIS

Since a zone is a space in which the interactions between the adversary and the physical protection system occur, analysis of those interactions by means of generic logic trees requires selection of the correct logic trees to describe the actions which can occur within the zone. Before that can be done, the zone must be described. The description should be done during design when the performance goals for the physical protection system are set. The location of the zone depends on the threat, its tactics, and its objective. As a practical matter the location of the zone further depends upon site physical attributes.

Outsiders must attempt to penetrate the site from the outside, whatever their objective may be. The initial boundary of the zone (the envelope of first potential detection) can reasonably be placed near (at or within) the property line of the site. Detection would be undesirable where the public could not be prohibited since alarms would be generated by innocent passersby as well as by adversaries.

In these circumstances, an adversary could only be identified as such if he were detected while committing an unauthorized act.

The final boundary of the zone (the envelope of termination of the attack) can have several possible locations depending on the type of adversary, the objective of the attack, and the speed of the response force. When the objective is sabotage, it may be reasonable, given a sufficiently fast response force, to prevent the adversary from entering the building that houses his target(s). In this case, the outside of the building may be specified as a final boundary of the zone. Such a zone would be a hollow shell surrounding the targets (which are inside the building).

If the object remains sabotage, but the response force cannot intercept the adversary before he enters the building that houses the target, then the PFS might be designed to accumulate enough delay for a response force to intercept the adversary by requiring the adversary to sequentially disable several targets but not enough to achieve an overall sabotage objective. It might not be possible to make the adversary sabotage the targets in a specific order. It is then not possible to predict which target(s) will not have been sabotaged when the attack has been terminated. Those targets which have not been sabotaged are enclosed by the final boundary of the zone. The analyst might think of the zone for this case as equivalent to a spheroid containing some number of bubbles (which are the unsabotaged targets).

If theft is the object of an attack, the final boundary at which the adversary is neutralized by a response force can be the property line of the site which may be virtually the same as the boundary for first detection. Alternatively, the final boundary might be placed at the outside of any building that houses targets.

Insiders can only be detected as adversaries when they commit an unauthorized act. The initial boundary should be placed where the first unauthorized act could be recognized as such.

Once the boundaries of the zone are established for the postulated threat, the generic logic trees needed for analysis can be selected. For the example of sabotage by outsiders, assume that the design of the physical protection system has established the initial boundary of the zone at the property line of the site, rising to a detection "roof" above the ground and descending to a detection "floor" below ground. Assume that the final boundary coincides with the outer walls, roof, and foundation of the hypothetical pressurized water reactor buildings.

The attackers must first penetrate the initial boundary. This action would be analyzed with the three boundary trees. All three boundary trees (DECEIT-BOUNDARY, FORCE-BOUNDARY, and STEALTH-BOUNDARY) must be used since the outsiders have a choice of tactics at this and every step of their attack. Between the initial boundary and the final boundary, the outsiders may travel across open terrain. This action would be analyzed with the three area trees (DECEIT-AREA, FORCE-AREA, and STEALTH-AREA). At the final boundary, it is possible that the delay needed

by the physical protection system to interrupt the attack and terminate it will be provided by the barrier of the building structure. The two building trees (FORCE-BUILDING and STEALTH-BUILDING) must be used, and the DECEIT-BOUNDARY tree must be used again, this time to analyze entry into the building.

If the design of the physical protection system is found to be adequate through the use of these trees that describe actions within the zone, there is no need to analyze the release trees. If the design is shown to be inadequate, the analyst might relocate the final boundary. The design of the system may prove adequate to protect the facility from a release of nuclear materials even though it could not terminate the attack as quickly as desired. It then becomes an option of the redesign either to move the final boundary of the zone or to improve the physical protection system. Of course, if the release cannot reliably be prevented, there is no choice but to redesign the system.

As the final boundary is located deeper within the building, it becomes necessary to take into account how physical protection is provided for each member of a set of vital areas. The sets of vital areas with the fewest members should be analyzed before those with more members. The analysis must continue either until a set is found for which physical protection is adequate or until it is found that no set has adequate physical protection. For these several analyses, the appropriate generic logic trees are selected and revised as needed.

Assuming that the analyst evaluates the physical protection of the vital components themselves, what additional generic logic trees would be analyzed? For example, assume that the adversary chooses to damage the reactor vessel itself so that adequate cooling to avoid a meltdown is impossible. The adversary must enter the reactor containment to reach the reactor vessel, as shown in Figure 6. He might choose to penetrate from the outside directly into the containment through the wall. This would require the use of force, or he might choose to enter the auxiliary building, perhaps by the door close to the personnel hatch of the containment. This might be accomplished by any of the three tactics. Penetration of either the auxiliary building or the containment structure is already subject to analysis with the last trees mentioned above (FORCE-BUILDING, STEALTH-BUILDING, and DECEIT-BOUNDARY). From this point on, new analysis is required. From the door of the auxiliary building to the personnel hatch, the adversary must travel across an area. The generic logic trees, DECEIT-AREA, FORCE-AREA, and STEALTH-AREA, are analyzed again. Their first analysis involved travel outdoors; this time the travel is within a building. Quite different elements of a physical protection system may be involved in the two situations. Nevertheless, the same generic trees are suitable in both situations.

The adversary's entry into the containment through the personnel hatch (a device designed as an airlock) is analogous to entering a building through a vestibule. This implies that the logic trees to analyze are DECEIT-BOUNDARY, FORCE-BUILDING, and STEALTH-BUILDING. Travel through the containment structure to the location from which the reactor vessel can be sabotaged is analyzed with the

DECEIT-AREA, FORCE-AREA, and STEALTH-AREA trees. Finally, the sabotage itself is analyzed with the FORCE-RELEASE and STEALTH-RELEASE trees. Table 3 contains a summary of the trees selected in this example.

Table 3

Generic Logic Trees Used to Analyze an Attack by Outsiders
on a Simplified Pressurized Water Reactor

Action	Trees
WITHIN ZONE	
Penetrate initial boundary	DECEIT-BOUNDARY FORCE-BOUNDARY STEALTH-BOUNDARY
Travel to reactor buildings	DECEIT-AREA FORCE-AREA STEALTH-AREA
Enter auxiliary building or containment	DECEIT-BOUNDARY FORCE-BUILDING STEALTH-BUILDING
OPTIONAL ANALYSIS OF VITAL COMPONENT SABOTAGE	
Travel to personnel hatch	DECEIT-AREA FORCE-AREA STEALTH-AREA
Enter containment through personnel hatch	DECEIT-BOUNDARY FORCE-BUILDING STEALTH-BUILDING
Travel through containment to location for sabotage	DECEIT-AREA FORCE-AREA STEALTH-AREA
Commit sabotage leading to core meltdown and release of nuclear materials	FORCE-RELEASE STEALTH-RELEASE

READING LOGIC TREES

Before the generic logic trees are used, their content and the method of reading them must be understood. The primary events of each of the 13 generic logic trees can be divided into 2 groups. The first group concerns the adversary's need to accomplish the end event of the tree whether it be crossing a boundary, travelling across an area, entering or leaving a building, acquiring special nuclear materials, or causing a release of special nuclear materials. The second group concerns the adversary's need to remain undetected (when using stealth or deceit tactics) or to overcome any opposition that he encounters (when using force tactics). The adversary using stealth or deceit tactics might need to overcome unexpected opposition, but if the stealth or deceit tactics are to be continued, the adversary must overcome his opposition without an alarm being generated, i.e., opposition must be considered as detection elements to be disabled by the adversary.

The DECEIT-BOUNDARY tree combines two goals: (1) the adversary himself crossing the boundary and (2) smuggling contraband across the boundary. For

convenience of discussion, the primary events for each goal have been treated separately, and the two collections of events have each been divided into two groups as above. Consequently, four groups of primary events are identified and discussed for the DECSIT-BOUNDARY tree.

Physically, accomplishing any of the end events is readily possible unless one or more barriers are present. Thus the primary events for boundary crossing relate to barriers that must be overcome. The qualitative question to ask is, "Can the adversary overcome the barrier(s)?" The answer is generally "yes," if the adversary is suitably skilled and equipped. The analyst must have a particular threat in mind if qualitative analysis of these events is to be meaningful.

The adversary will remain undetected while striving to accomplish the end event of a logic tree unless detection elements are present. Thus, the primary events for detection relate to detection elements that must be avoided, disabled, or deceived (using stealth or deceit tactics), or ignored (using force tactics). For stealth and deceit trees the qualitative question to ask is, "Is it likely that the adversary can avoid, disable, or deceive the detection elements without an alarm being generated?" For force trees the adversary will ignore detection elements by definition. But human detection elements might oppose the adversary's progress, so the qualitative question to ask is, "Is it likely that the adversary can overcome any opposition that he encounters?" To answer "no" to these questions, the analyst must be convinced that the detection elements (or the opposition) provide positive measures. The detection elements (or opposition) must operate under virtually any attack that the assumed threat can mount. Data from field tests of performance and vulnerability could provide persuasive support to claims of design effectiveness. To answer "yes," the analyst must find the detection elements vulnerable to an attack within the capability of the assumed threat. Whether this is a significant defect can only be determined by evaluating the whole logic tree.

If the adversary is not permanently stopped by some barrier within the zone, it will be necessary to perform a quantitative analysis* to estimate whether a response force can intercept the adversary in time to prevent him from achieving his objective. The analyst evaluates the boundary crossing events on a tree by asking

*EASI, Estimate of Adversary Sequence Interruption, is among the simplest of the quantitative analyses to use. See the following:

H. A. Bennett, The "EASI" Approach to Physical Security Evaluation, NUREG 760145 (Albuquerque: Sandia National Laboratories, January 1977).

D. W. Sasser, EASI on the HP-25, HP-65, and HP-67, NUREG-0231 (Albuquerque: Sandia National Laboratories, May 1977).

H. A. Bennett, User's Guide for Evaluating Physical Security Capabilities of Nuclear Facilities by the EASI Method, NUREG-0184 (Albuquerque: Sandia National Laboratories, June 1977).

D. W. Sasser, User's Guide for EASI Graphics, SAND78-0112 (Albuquerque: Sandia National Laboratories, March 1978).

H. A. Bennett and D. W. Sasser, EASI Program Improvements for HP-67 and TI-59 Calculators, NUREG/CR-0350 (Albuquerque: Sandia National Laboratories, July 1978).

the quantitative question, "How much time will the adversary use to overcome the barrier(s)?" This time is the delay provided by the barrier(s). It is also called a task time.

The analyst evaluates the detection events on a tree by asking the quantitative question, "What is the probability that the adversary will be detected as he strives to accomplish the end event of the logic tree?" These probabilities of detection (and associated standard deviations) are data used in quantitative evaluation.

"BOUNDARY" GENERIC LOGIC TREES

There are three generic logic trees: one each for crossing the boundary by stealth, force, and deceit tactics. The primary events of each tree can be divided into two groups. One group concerns the adversary's need to cross the boundary. The other group concerns the adversary's need to remain undetected (stealth and deceit trees) or to overcome any opposition that he encounters while he crosses the boundary. The logic tree DECEIT-BOUNDARY has two cases for each group: (1) the adversary himself crossing the boundary and (2) smuggling contraband across the boundary.

Contraband is explicitly considered only in the deceit logic tree. The adversary using force tactics and carrying contraband is, by definition, unconcerned about detection either of it or of himself. The analyst should take into account the effect of the contraband as a burden. The adversary using stealth tactics and carrying contraband tries to avoid detection. He does so, generally, by crossing a boundary where there are no special detection systems to sense explosives, metal, or SNM. The analyst should take into account the effect of the contraband as a burden and the possibility that a sensor will sense material carried by the adversary as well as, or rather than, the adversary himself.

One question to ask in a qualitative evaluation of the logic tree is, "Can the adversary overcome the barrier(s) to crossing the boundary?" For the deceit and stealth trees a second question is, "Is it likely that the adversary can avoid, disable, or deceive the detection elements without an alarm being generated?" For the force tree a second question is, "Is it likely that the adversary can overcome any opposition that he encounters?"

If a quantitative evaluation is needed, one question is, "How much time will the adversary need to overcome the barrier(s) to crossing the boundary?" The other quantitative question is, "What is the probability that the adversary will be detected as he crosses the boundary?"

STEALTH-BOUNDARY

Figure 7 shows a simplified version of the generic logic tree, STEALTH-BOUNDARY. This tree gives general logic for defeat of a boundary by stealth tactics. There are 10 primary events (S1-1, S1-3, S2-1, S2-3, S2-4, S3-1, S3-2, S3-3, S3-4, and SX3-5). These can be divided into two groups. One group concerns the

adversary's need to get across the boundary (S2-1, S3-1, S3-2, S3-3, and S3-4). The other group concerns the adversary's need to remain undetected while the boundary crossing is made (S1-1, S1-3, S2-3, S2-4, and SX3-5).

The logic tree assumes the boundary has two parts. In one part, crossings are made normally, i.e., through a gate or portal (see event S2-1); in the other, crossings are prohibited, i.e., everywhere other than a gate or portal (see events S3-1, S3-2, and S3-4). These two parts of the boundary should present different problems to the adversary.

The elements of the physical protection system at the gate or portal are not named in event S2-1. It is the analyst's job to supply these elements from the design which he is evaluating. However, S2-1 is a developed event; it is further developed on the complete generic logic tree, STEALTH-BOUNDARY. That development is ignored in this discussion.

Along the boundary elsewhere than at the gates or portals, one kind of element is so frequently used that it is specified by the development of S2-2. That element is a fence or two fences with a cleared space between them (S3-1, S3-2, S3-4). All other possible kinds of barriers (including any which impede an attack from above-ground or underground) are covered by event S3-3.

Three kinds of elements detect boundary crossings. One is located at entrances (S2-1, a developed event). No examples are named on the simplified logic tree. One or more guards posted at the entrance may be used. But guards alone may not be a positive measure for detection.

A second kind of element senses along the boundary but not necessarily at entrances (SX3-5, a developed event). No examples of the sensors are named on the simplified logic tree. A combination of sensors may be used. The analyst's job is to evaluate whether the combination produces a positive measure for detection.

The third kind of element operates anywhere along the boundary, both at and away from entrances (S1-1, S1-3, S2-3, S2-4). Guards on patrol or stationed in observation towers are one example (S2-3, S2-4). If they alone could not be a positive measure for detection, they may reinforce the other kinds of detection elements to produce a positive measure.

The two events that name guards as detection elements list two ways that an adversary may not be detected. He can avoid being seen by the guards (S2-3), or, if he is seen, he may be able to prevent the guards from sounding an alarm (S2-4). While the latter method of avoiding detection may be forceful rather than stealthy, it represents an action required of the adversary if he is to continue his attack by stealth, undetected, after he accidentally confronts a guard. In general, the adversary will probably be able to see where patrol guards are and cross the boundary when they are absent and unable to see the adversary. It may be difficult for an adversary to know whether or not he is being seen from an observation tower or to prevent the sounding of an alarm if he knows that he has been seen.

Operations personnel may be nearby and see the adversary when he crosses the boundary (S1-3). In many instances, the adversary should be able to avoid them. Confrontation would be an unintended complication of an attack by stealth, and it may increase the chance of being seen by a guard in an observation tower.

Reinforcements for the protective force (S1-1) would be called only after detection. The time between notification of the protective force and its arrival could be long enough to prevent the force from intercepting the adversary during the boundary crossing that gave rise to the detection. Thus, this event may have no relevance for the crossing of the initial boundary of the zone. It may be meaningful with respect to crossing a boundary within the zone after detection has occurred.

Having examined all primary events on the simplified logic tree, the logic by which the primary events generate the end event is now examined. The adversary must cross the boundary and he must avoid detection while doing so. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by the AND gate S-BOUNDARY. The input for crossing the boundary comes from event S1-2. All three other inputs (S1-1, S1-3, S1-4) supply requirements for avoiding detection by the elements that can operate anywhere on the boundary, regardless of where the crossing is made.

The elements that detect only at entrances or only away from entrances must be associated with those optional locations for crossing the boundary. The optional crossing locations are inputs S2-1 and S2-2 to the OR gate S1-2. Crossing the boundary at an entrance (S2-1) is a developed primary event. But crossing the boundary away from an entrance (S2-2) is generated by an AND gate which repeats the fundamental logical statement of the logic tree. Crossing the boundary away from an entrance requires that four events (S3-1, S3-2, S3-3, S3-4) be performed. These four events are inputs to the AND gate S2-2. Avoiding detection during the crossing is represented by the single developed event SX3-5, which is an input to the AND gate S2-2.

One other development appears on the tree. Event S1-4, "Avoid or Confront Guards Undetected," states an option. The necessary logic is an OR gate, S1-4, with inputs S2-3 and S2-4. This same sort of option is implied for S1-1 and S1-3. Their developments would have the same logical form as the development of S1-4.

FORCE-BOUNDARY

Figure 8 shows a simplified version of the generic logic tree, FORCE-BOUNDARY. This tree gives general logic for defeat of a boundary by force tactics. There are 9 primary events (F1-1, F1-3, F2-1, F2-3, F2-4, F3-1, F3-2, F3-3, F3-4). These can be divided into two groups. One group concerns the adversary's need to get across the boundary (F2-1, F3-1, F3-2, F3-3, F3-4). The other group concerns the adversary's need to overcome any opposition that he encounters while the boundary crossing is made (F1-1, F1-3, F2-3, F2-4). Every event but one on STEALTH-BOUNDARY has a

Figure 8. FORCE-BOUNDARY Logic Tree

counterpart on FORCE-BOUNDARY. The exception is SX3-5, "Defeat or Bypass Detection System." By definition, when using the force tactic the adversary expects to be detected, so the FORCE trees have no events that require the adversary to take action against the detection system.

DECEIT-BOUNDARY

Figures 9, 10, and 11 show a simplified version of the generic logic tree, DECEIT-BOUNDARY. There are 23 primary events (DI-1, DX1-3, DX2-1, DX2-2, DX3-3, DX2-4, DX2-5, DX2-6, DX2-9, DX2-11, DX3-1, DX3-2, DX3-4, DX3-5, DX3-6, DX4-1, DX4-2, DX4-3, DX4-4, DX4-5, DX4-6, DX4-7, DX4-8). They can be divided into four groups. One group concerns the adversary's need to get across the boundary himself (DI-1, DX2-1, DX2-6, DX4-1, DX4-2). The second group concerns the adversary's need to remain undetected while crossing the boundary (DX1-3, DX2-2, DX2-3, DX2-7, DX2-8, DX3-1, DX3-2, DX3-4, DX3-5, DX3-6). The third group concerns the adversary's possible need to smuggle contraband across the boundary (DX2-9, DX2-11). The fourth group concerns the adversary's need to avoid detection of the contraband which might be smuggling (DX4-3, DX4-4, DX4-5, DX4-6, DX4-7, DX4-8).

Questions to ask in a qualitative evaluation of DECEIT-BOUNDARY are, "Can the adversary overcome the barrier(s) to crossing the boundary at an entrance?" and, "Can the adversary smuggle so that the contraband passes the barrier(s)?" and "Can the adversary almost always avoid, disable, or deceive the detection elements so that detection of neither adversary nor contraband occurs?" For both insider and outsider adversaries the answers depend on the features of the physical protection system at the entrance, on the particular threat and contraband, and on the skills and preparation of the adversary.

If a quantitative evaluation is needed, one question is, "How much time will the adversary need to overcome the barrier(s) to crossing the boundary himself and to smuggling contraband?" The other quantitative question is, "What is the probability that the adversary or the contraband will be detected as the boundary is crossed?"

The logic tree is concerned with only one part of the boundary, the entrance. Crossings are made normally, i.e., through a gate or portal (see event DI-1). The elements of the physical protection system at the gate or portal are not named in basic event DI-1. This event is in effect merely a label, reminding the analyst that normality of route and procedure is the essential characteristic of all deceit scenarios.

Insiders crossing the boundary by deceit will have no difficulty except accidentally through some failure of the physical protection system. The insider will by definition have authentic credentials to establish his identity (see event DX2-1). An outsider who obtained identity credentials made on the same equipment with the same materials in the same manner as all authentic credentials, and obtained through an insider, would satisfy this event. His credentials would have no flaw and thus would not be detectable as counterfeit.

Figure 9. DECEIT-BOUNDARY Logic Tree

Figure 10. DECEIT-BOUNDARY, Two-Man Rule Logic Tree

Figure 11. DECEIT-BOUNDARY, Smuggle Contraband Logic Tree

If the insider is authorized to cross the particular boundary in question when he seeks to do so, he will by definition be correctly authorized (see event DX2-5). An outsider who has had authorization established in the physical protection system in the same manner as all correct authorizations, probably accomplished through an insider, would satisfy this event. His authorization would have no flaw and thus would not be detectable as counterfeit.

If at the boundary in question a two-man rule is initiated, the adversary should not be allowed to proceed alone regardless of the acceptability of his identity credentials or authorization. An adversary could try to defeat the physical protection system by having another, collaborating adversary act as the second man required for the physical protection system to admit the two adversary team (see event DX4-1). In this case the second adversary, as well as the first, must be analyzed for his ability to defeat the logic tree DECEIT-BOUNDARY (see event DX4-2).

If an adversary is attempting to smuggle contraband across the boundary his success in personally crossing the boundary becomes conditional on the success of the smuggling, and vice versa. Three classes of smuggling are included on the logic tree. The first class concerns openly removing SNM with some authorization from within the boundary (see event DX2-9). This is a developed event; it is further developed on the complete generic logic tree, DECEIT-BOUNDARY.

The second class concerns smuggling contraband without any pretense of authorization by hiding or disguising it. Examples noted on the logic tree are explosives (which an adversary would smuggle into an area from outside the boundary) and SNM (which an adversary would smuggle out of an area from inside the boundary). The accomplishment of the smuggling is not tied explicitly to an event in the development of DX2-10. The analyst is to assume that if the adversary can satisfy the development, i.e., if the contraband is not detected, then the contraband is successfully smuggled.

The third class merely exists to collect other possibilities (see event DX2-11). For example, smuggling of tools or weapons is not covered by the first two classes. This event also notes that the contraband might be smuggled whole or in disassembled elements. Event DX2-11 is undeveloped.

All the kinds of elements that detect boundary crossings by deceit are located at entrances. The heart of a typical detection system is a check of identity and authorization to cross the boundary (DX2-2, DX2-3, DX2-7, DX2-8). Depending on the boundary in question, the authorization may be conditional on adherence to a two-man rule (DX3-1, DX3-2, DX3-4, DX3-5, DX3-6). Furthermore, permission to complete the crossing of the boundary may be made conditional on the examination for contraband of any material that may be taken across the boundary (DX4-3, DX4-4, DX4-5, DX4-6, DX4-7, DX4-8). These are the formal parts of the physical protection system. Another feature which is not generally a designed part of a physical protection system is the miscellaneous personnel who happen to be at the entrance at the same time as the adversary and who have the potential capability to observe and react to suspicious behavior that the adversary might exhibit (DX1-3).

The adversary with a counterfeit identity credential needs to defeat the check of his credential by the physical protection system (DX2-2). A counterfeit is a copy or imitation. A counterfeit credential can be more or less like an authentic one, but in some feature it must differ from an authentic credential. The likelihood of the physical protection system detecting the counterfeit credential depends on its sensitivity to the difference between a particular kind of counterfeit and an authentic credential, and on the difference between the counterfeit credential and the reference data used by the physical protection system to check the identity credential. For example, an authentic picture badge might be a particular size, shape, color, construction, contain particular information, etc. It must also have a picture of the bearer that can be matched against his appearance as well, perhaps, as against a reference picture in a secure archive. A's authentic badge would be considered counterfeit by the analyst if carried by B and presented to the physical protection system for checking. None of these considerations are made explicit in the logic tree; event DX2-2 is undeveloped.

The adversary with no identity credentials needs to avoid or defeat the credential check by the physical protection system (DX2-3). The adversary might risk joining a heavy flow of personnel through the entrance, hoping to cross the boundary anonymously in the midst of the crowd, avoiding the credential check. He might attempt the excuse that he had forgotten his identity credential, with the hope or the knowledge that the physical protection system does not require some rigorous alternate identity check. Or the adversary may play the role of someone not expected to carry the identity credential such as visitors or vendors who have legitimate business across the boundary. The physical protection system must be able either to sort out an adversary from those who have legitimate business across the boundary, or to control the movement and activities of persons who are allowed to cross the boundary without the required identity credential. Another possible defeat of the physical protection system is to have the credential checker collaborate with the adversary. None of these considerations are made explicit in the logic tree; event DX2-3 is undeveloped.

The adversary who has counterfeit authorization to enter the area across the boundary needs to defeat the check of his authorization by the physical protection system (DX2-7). Whether both the authorization check and the identity check must be defeated depends on the design of the physical protection system and, perhaps, on the boundary to be crossed and the area to be entered. Generally, the authorization check must be passed to secure permission to cross the boundary, while the identity check must be passed to enable the authorization check to be made securely. A counterfeit authorization is analogous to a counterfeit identity credential. The counterfeit is a copy or imitation and must differ from an authentic authorization. If the authorization is merely a visible feature of an identification badge (e.g., a symbol or special color, etc.) counterfeiting the identity credential would simultaneously accomplish counterfeiting the authorization. The two physical protection features would have no independence, and defeat of one would imply defeat of the other. In contrast, suppose the authorization is kept in a file possessed by the physical protection system rather than possessed by the person seeking to cross the boundary. An adversary need either impersonate someone known to have the desired

authorization or he must somehow have the desired authorization of himself inserted into the file. In this case, the adversary runs a double risk. The file entry must be made without detection, and the file entry must be made correctly if it is not to be detectable as a counterfeit authorization. These comments are applicable to a badge exchange system and, as well, to a file of paper authorizations or a computerized authorization file. None of these considerations are made explicit in the logic tree; event DX2-7 is undeveloped.

The adversary who is not authorized access through the boundary needs to find a way to be accepted by the physical protection system (DX2-8). The adversary might risk joining a heavy flow of personnel through the entrance, hoping to cross the boundary anonymously in the midst of the crowd, avoiding the authorization check (and the identity credential check, as described in connection with event DX2-3). If the physical protection system is designed for personnel to carry authorization credentials, an adversary might attempt the excuse that he had forgotten his, with the hope or knowledge that the system does not require some rigorous alternate authorization check. Or the adversary may play the role of someone not expected to have an authorization in his possession or on file, such as a visitor or vendor who has legitimate business across the boundary. The physical protection system must be able either to sort out the adversary from those who have legitimate business across the boundary, or to control the movement and activities of persons who are allowed to cross the boundary without the required authorization for access. Another possible defeat of the physical protection system is to have the authorization checker collaborate with the adversary. None of these considerations are made explicit in the logic tree; event DX2-8 is undeveloped.

Five primary events (DX3-1, DX3-2, DX3-4, DX3-5, DX3-6) relate to the adversary's need to avoid detection arising from use of a two-man rule while crossing a boundary. One possibility (DX3-1) is that the adversary deceives the second man. In merely crossing a boundary, an adversary probably need not commit an observable unauthorized act, so the second man, crossing with him, would have no effective way to question the adversary's intentions. This event is more meaningful as a barrier to the adversary if he is impersonating someone known to the second man. The significance of event DX3-1 is strongly scenario dependent; the event is undeveloped.

A second possibility (DX3-2) is that the adversary has the collaboration of the second person and that the second person is an insider. This is a basic event. The problem for the analyst to decide is whether it is credible that an insider will collaborate (either willingly or under coercion). The case where the collaborating second man is an outsider has been discussed as a need of an adversary to get across the boundary (events DX4-1 and DX4-2).

A third possibility (DX3-4) is that the adversary crosses the boundary alone by exploiting, and possibly causing, a failure of the physical protection system to enforce the two-man rule. The event is undeveloped. Open questions are how might the physical protection system fail to enforce the two-man rule and how would the adversary become aware of the failure, if he did not cause it, so that he could exploit it.

A fourth possibility (DX3-5) is that the adversary crosses the boundary alone because the person who should have enforced the two-man rule collaborates with the adversary. This is a basic event.

The fifth and last possibility included in the logic tree (DX3-6) is that the adversary crosses the boundary alone by persuading enforcement personnel that no second person is required. This event is plausible if the adversary is or poses as a high-level executive of the site in question. There is a chance that the enforcement personnel could be intimidated by such an adversary. An adversary might also attempt to persuade the enforcement personnel that he should cross the boundary alone on the pretext that the action is required by an emergency that the adversary has caused to be reported. This event is undeveloped.

The adversary's need to avoid detection of the contraband which he might be smuggling is covered by six primary events (DX4-3, DX4-4, DX4-5, DX4-6, DX4-7, DX4-8).

The first group of these events concerns the adversary's need to defeat any search of his person, possessions, or vehicle. One possibility (DX4-3) is that the search is made by a gate guard and it fails to find the contraband. Since the use of detectors is treated elsewhere in the logic tree, the analyst should assume that the "search by gate guard" is conducted manually and by direct visual observation. Adversary success implies that the contraband is sufficiently well disguised and hidden and that the manual, visual search is not capable, perhaps inherently, perhaps through some peculiarity of the particular search process being analyzed, of consistently finding contraband. This is a basic event.

The second possibility (DX4-4) is that a gate guard will collaborate with the adversary by failing to report any contraband that he finds during the search, or by not conducting the search. This is a basic event.

The third possibility (DX4-5) is that the adversary defeats the search for contraband because the gate guard, through carelessness, forgetfulness, or indifference (but not through deliberate collusion with the adversary) fails to search for contraband. If searches were only conducted on a random spot-check basis they would be included in this event. An adversary would need accurate inside information to make a realistic assessment of his risk in making use of this basic event.

The second group of three events concerns the adversary's need to defeat detectors, if any, of contraband (explosives or SWM). One possibility (DX4-6) is that a guard collaborates with the adversary by assisting in the defeat of the detector(s). This is a developed event.

The second possibility (DX4-7) is that the adversary successfully shields the contraband from the detector(s). Evaluation of the adversary's possible success is strongly dependent upon scenario and physical protection system data. For example, what and how much is being smuggled, what are its characteristics, how is it shielded, and how sensitive are the detector(s) to the characteristics of the contraband as attenuated by the shielding. This is a basic event.

The third and final possibility (DX4-8) is that the adversary defeats the detector(s). Since defeat by shielding and by collaboration have already been considered, the remaining method of defeat implied by this developed event is tampering with the detection system itself so that it will not indicate the presence of contraband. This is made explicitly clear on the development of DX4-8 which appears on the complete logic tree, D-BOUNDARY.

Having examined all primary events on the simplified logic tree, the logic by which they generate the end event is examined next. The adversary must cross the boundary, and he must avoid detection while doing so. He may smuggle contraband across the boundary and, if so, he must avoid detection of the contraband. This is the fundamental statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by AND gate D-BOUNDARY. The input for crossing the boundary comes from event D1-1. The input for avoiding detection while crossing the boundary comes from events DX1-2, DX1-3, DX1-4, and DX1-5. The input for smuggling contraband across the boundary without detection comes from event DX1-6.

The types of identity credentials which an adversary might use (DX2-1, DX2-2, DX2-3), expressed in terms of the degree of the adversary's detectability, complete the development of DX1-2 as inputs to an OR gate.

The types of authorization which an adversary might have (DX2-6, DX2-7, DX2-8), expressed in terms of the degree of the adversary's detectability, complete the development of DX1-5 as inputs to an OR gate.

The adversary's options for defeating a two-man rule (DX3-1, DX3-2, DX3-3, DX3-4, DX3-5, DX3-6) constitute the development of DX1-4 as inputs to OR gates. For ease of reading this portion of the logic tree DX3-1, DX3-2, and DX3-3 are grouped as inputs to OR gate DX2-4. Event DX2-4 merely labels its inputs as all dealing with options in which a second man does cross the boundary with the adversary. Events DX3-4, DX3-5, and DX3-6 are grouped as inputs to OR gate DX2-5. Event DX2-5 merely labels its inputs as all dealing with options in which a second man does not cross the boundary with the adversary. The two "label" events, DX2-4 and DX2-5, are the inputs to OR gate DX1-4. Finally, DX4-1 and DX4-2 are pseudo-events (equivalent to comments) pertaining to event DX3-3. They remind the analyst of two things that are concurrently relevant: that the second man can also be an adversary and that this additional adversary must be analyzed by the full tree, D-BOUNDARY. So, DX4-1 and DX4-2 are inputs to AND gate DX3-3.

The adversary's options for smuggling contraband (DX2-9, DX2-10, DX2-11) begin the development of DX1-6 as inputs to an OR gate. The basis for differentiating among the options is whether the contraband is smuggled in the open (DX2-9), i.e., with some authorization or pretense of authorization, or whether the contraband is hidden or disguised for smuggling (DX2-10), i.e., authorization is not a consideration. The most important contraband is SNM and explosives. The remaining input to DX1-6 recognizes that other contraband such as tools or weapons might also be important (DX2-11).

The abridged logic tree, D-BOUNDARY, has room for development of only one of the above inputs to DX1-6, specifically, DX2-10. The inputs to AND gate DX2-10 are the elements of the physical protection system which the adversary must defeat: specifically, the various possible manual, visual searches (DX3-7) and the various possible hardware detectors that might supplement or substitute for manual, visual search (DX3-8). The adversary's options for defeating the search(es) and detector(s) complete the development of the contraband smuggling event (DX1-6). Options DX4-3, DX4-4, and DX4-5 are inputs to OR gate DX3-7. Options DX4-6, DX4-7, and DX4-8 are inputs to OR gate DX3-8. One more level of development can be found for DX4-6 and DX4-8 on the complete logic tree, D-BOUNDARY.

4. SYSTEM DESIGN / ANALYSIS TECHNIQUE

DESIGN / ANALYSIS CYCLE

Analysis of the effectiveness of the physical protection of nuclear facilities and materials is part of the cycle of design and analysis shown in Figure 12.

Figure 12. Design/Analysis Cycle

The cycle begins with the initial design of a PPS. The qualitative effectiveness of the PPS is then analysed against a range of threats. The results of the analysis answers the question, "Is the physical protection system adequate or inadequate?" If the PPS is found to be adequate, the design/analysis cycle ends. If the system is found to be inadequate, it must be redesigned. Weaknesses identified by the analysis must be improved. The design/analysis cycle is closed by analysis of the redesigned system. The cycle is repeated until an adequately effective design is achieved. The credibility of the design of the PPS is enhanced by the fact that total system performance is analyzed.

Figure 13 introduces information which must be collected and organized in the design/analysis cycle. It also differentiates among three types of loop in the overall cycle. The design and analysis of a physical protection system for a nuclear facility involves six basic steps:

1. Assess the threat,
2. Characterize the facility,
3. Define the objectives,
4. Set parameters,
5. Develop or modify system concepts,
6. Analyze the design, and depending on the outcome,
 - a) End the cycle if the system is sufficiently effective, or
 - b) Loop to complete or improve the design.

The first two steps (assess threat and characterize facility) gather and organize information; together with the third step (define objectives) they define the general design/analysis problem.

In the fourth step (set parameters), the general problem is split into several specific problems whose parameters have values that cover the expected range. Targets are a physical protection parameter; all targets must be considered before the design/analysis process stops.

The fifth step (develop or modify system concepts), solves one specific problem at a time. An effective system can be achieved by iteration, at each step finding combinations of system elements to provide positive measures for all four functions of the physical protection system.

The sixth step (analyze the design), qualitatively analyzes whether the conceptual design consists of positive measures. This design/analysis method is iterative after the analysis step. The conceptual design may need modification before it is judged capable of achieving its objectives (return to step 5, system concepts). Parameter values must be changed until the conceptual design solves the whole problem in an integrated manner (return to step 4, set parameters). It is possible that after many negative evaluations the objectives must be modified (return to step 3, define objectives).

Simplifying Design and Analysis

The physical protection problem can be illustrated by logic trees. Logic tree PPS (Figure 14) has end event "Defeat Physical Protection System" generated by an OR gate. The adversary can defeat the physical protection system by defeating any of its four necessary functions: detection, delay, communication, or response. This tree is simply a logical statement of the physical protection problem as viewed by the adversary. The adversary "wins" if any one of the events is accomplished, and the physical protection system "wins" if it prevents the adversary from accomplishing all of the events.

Figure 13. Design/Analysis Information and Loops

Figure 14. Logic Tree PPS

Review of the information required about the adversary and the facility will convince the designer and analyst that they are dealing with a very complex problem. The zone concept provides a focal point for the design and analysis of an effective physical protection system and helps limit the problem to a size that can be solved.

The selection of the zone depends upon the site, the threat, threat tactics, and threat objectives. For an existing site, the dominant criterion for initial selection of a zone may be to place the zone where most of the existing detection and delay elements, if any, are located. This maximizes use of existing elements and operations, but may not minimize the operational and financial impact on the site.

Significant analytic complexity is avoided by limiting consideration to the physical protection system acting within the zone. In some cases, this simplification is sufficient to make the design and analysis problem solvable. If the physical protection system is effective, the threat will be neutralized within the zone. Questions can be asked about any supplementary physical protection functions beyond the zone: detection before the zone is penetrated, delay beyond the zone, or response to intercept the attackers after they have departed from the zone. The protective force, for example, would certainly take advantage of detecting an adversary prior to zone penetration and would continue a battle, if necessary, beyond the zone. Safeguards that act outside the zone are not part of the PPS and would unnecessarily complicate the analysis.

The role of the zone in a physical protection system is introduced in logic tree PPS-DET (Figure 15) and PPS-DEL (Figure 16). The end event of logic tree PPS-DET (Figure 15), "Defeat PPS Detection Function," is generated by an AND gate and can be accomplished if the adversary defeats both the zone detection function (ZONE-DET) and detection functions other than those designed into the system (DET-1). Since the adversary must do both for success, it is sufficient for the

Figure 15. Logic Tree PPS-DET

Figure 16. Logic Tree PPS-DEL

physical protection system to prevent the adversary from accomplishing ZONE-DET. The physical protection system is designed to detect and halt attacks within the zone, so the analysis will evaluate event ZONE-DET. Event DET-1 refers to factors that are not part of the physical protection system design, so DET-1 will not be evaluated. Logic tree PPS-DEL (Figure 16) similarly develops the delay function.

Timely communication and response that can intercept and neutralize the adversary within the zone must also be designed into the system. For example, the response force must carry out its initial interception within the zone since that is where positive measures exist to track and delay the adversary.

Development of the zone detection function is given in logic tree ZONE-DET (Figure 17). The adversary may attempt to defeat detection while using force (DET-FORCE), stealth (DET-STEALTH), or deceit tactics (DET-DECEIT).

Event DET-FORCE is bounded by event DET-STEALTH. This assumes that any attack using force tactics will be detected at least as easily as if the adversary had been using stealth (or deceit) tactics. As long as this assumption is true, the analyst can place a lower bound on the effectiveness of detection by examining only generic logic trees for stealth and deceit tactics. The development of DET-STEALTH and DET-DECEIT is found on these logic trees. Similarly, the detection function of a physical protection system can be designed with the aid of only the generic logic trees for stealth and deceit.

A similar development of the zone delay function is given in logic tree ZONE-DEL (Figure 18). The adversary may attempt to defeat the zone delay by the use of force (DEL-FORCE), stealth (DEL-STEALTH), or deceit tactics (DEL-DECEIT). Delay events are all conditioned upon previous detection of the adversary. Stealth and deceit events assume that the delay associated with these tactics will be at least as long as the delay associated with force tactics. This assumption is generally valid when adversary detection has previously occurred and when the PPS has design features such as adversary tracking while in the zone. If this assumption is valid, the stealth and deceit generic logic trees need not be used when evaluating the system delay function.

DESIGN / ANALYSIS TECHNIQUE

This design/analysis technique is qualitative and uses generic logic trees. Instructions for performing the six parts of physical protection design/analysis follow (see also Figure 13).

Begin by defining the general problem. This requires collection of information about the spectrum of potential adversaries (step 1), about the site, (step 2), and about the system objectives (step 3). Based on the objectives and the design of the physical protection system, identify the areas of the site where the system and the adversaries may interact. Then select the logic trees needed to trace the interactions between system and adversary.

Figure 17. Logic Tree ZONE-DET

Figure 18. Logic Tree ZONE-DEL

Fourth, select a specific problem for the design/analysis cycle. Threat and facility characteristics may be fixed as parameters by the analyst or designer. It simplifies the immediate problem but requires analysis and design to be completed over several iterations, changing the parameters to cover their expected range. Parameters may be associated with the threat, its plan of attack, and the facility. For example, see Tables 4, "Some Adversary Characteristics," and 5, "Some Important Facility Characteristics." In particular, one generic adversary must be selected from the spectrum of potential adversaries. Next choose the zone and logic trees most appropriate to the selected adversary's attack. It is not easy to design a system that is practical, economical, and effective against a well-trained, well-equipped threat consisting of several individuals. A suggested practice is to begin the analysis with an adversary rated near the weak end of the threat spectrum. This type of analysis has relatively few complications and can be done quickly. If this analysis shows that the initial design fails to offer satisfactory performance, relatively little effort has been used to establish that there is a need for improvement. Analysis of a redesigned system can reasonably begin with the least severe

threat that caused failure of the previous design. If the system is effective against a weak threat, the second analysis can use a threat from the strong end of the spectrum. If the design also passes this test, little effort has been used to test extremes of the threat spectrum. If the design fails the test of a strong threat, try a threat from the middle of the spectrum. A search strategy such as this can avoid a lengthy series of analyses where severity of threat is increased or decreased steadily by small amounts to cover the full spectrum.

Fifth, either accept a given design of a physical protection system for analysis, or make a conceptual design using logic trees. Based on threat assessment, facility characterization, and definition of objectives, and constrained by parameter settings, a designer can develop or modify physical protection system concepts. Elements that perform the required functions of the system may be assigned to chosen locations at the facility. Several options may be developed. The choice of which option to implement will be made after all options have been analyzed. There are three design activities to perform:

1. Provide all of the necessary physical protection functions to prevent the adversary's success.
2. Consider a variety of physical protection elements to oppose the adversary at each task. Include all existing features of the facility that might be useful for physical protection.
3. Select the elements to include in a physical protection system on the bases of cost-effectiveness and avoiding excessive redundancy. Recognize when one element can thwart several tasks and also when the logic of the tree permits an adversary to be thwarted without requiring an element to thwart the successful completion of every task.

Sixth, perform the qualitative analysis using logic trees. There are three questions to ask:

1. Does the physical protection system include all of the necessary functions? If not, name the missing functions.
2. Do the functions operate against all attacks that the selected threat can mount? If not, identify which functions are weak and the attacks by which they might fail.
3. Do the physical protection elements have positive measures? If not, list the deficiencies. If better elements are known, list them.

If the answers to these questions are all "yes," return to the fourth step (set parameters); otherwise design modification or a change of system objectives is required.

To select another specific problem by making a new setting of parameters for design/analysis requires, for the same adversary,

1. Selection of another tactic, a different time, or different environmental conditions for the attack, or
2. Selection of a different operational state of the facility;

or it requires selection of another adversary.

The design/analysis cycle is complete when the design of the physical protection system is shown to be potentially adequate after having been analyzed against the most severe attack which can be mounted by adversaries within the assumed spectrum. If the design fails, the analyst has the option of returning the design to step 5 for improvement, with only those weaknesses identified which were involved in the failure, or else analyzing further cases to find other possible weaknesses that were not tested by the case that first caused system failure. The latter procedure should make redesign more efficient. If operational impact, economics, or some other constraint precludes a design that is found to be potentially effective against the full threat spectrum, return to step 3 and reduce the spectrum or other system objectives and try again.

THREAT ASSESSMENT

To analyze or formulate physical protection concepts, a threat spectrum must be assumed, deduced, or otherwise established. To make an informed choice among physical protection concepts, the relative effectiveness of each concept needs to be evaluated using this threat spectrum. Some adversary characteristics are summarized in Table 4 and discussed below.

Table 4
Some Adversary Characteristics

1. Carrying capacity for tools and weapons,
2. Facility access (outsiders with no authorized access, employees or visitors with access, or outsiders in collusion with employees),
3. Knowledge of facility (layout, operations, and physical protection system),
4. Motivation,
5. Number of adversaries,
6. Skills (military and technical),
7. Special equipment (self-contained breathing apparatus, etc.),
8. Speed of performing tasks,
9. Tactics (deceit, force, stealth, or any combination of these),
10. Tools (cutting torch, explosives, ladder, lock pick, wire cutters, etc.),
11. Transportation (aircraft, boat, foot, ground vehicle, or a combination of these), and
12. Weapons (automatic rifle, club, hand gun, shotgun, etc.).

Information must be collected to answer three questions about the adversary:

1. Who is the adversary?
2. What are the adversary's capabilities?
3. What are the variables of the adversary's plan of attack?

Adversaries can be separated into three classes: (1) outsiders, (2) insiders, and (3) outsiders in collusion with insiders. For each class of adversary, the full range of tactics (deceit, force, stealth, or any combination of these) should be analyzed.

Important capabilities of the adversary include such items as his knowledge of the physical protection system, level of motivation, skills that would be useful in the attack, speed with which the actions that make up the attack are carried out, and capacity to carry tools and weapons. Since it is not generally possible to test and evaluate the capabilities of a known adversary, the analyst must make assumptions. These assumptions can be based on published information about human performance and tested vulnerability of physical protection elements.

Knowledge of the system can be gained in many ways. Fences, lights, some sensors and assessment devices, guard posts, and patrol schedules are among the things that can be directly observed from outside a protected site. Visitors may be able to observe some indoor system elements such as door switches, space alarms, and perhaps a security control center. Insiders would be able to gather extensive information over an extended period of time. They may obtain system plans; they may be part of the system. Obtaining extensive knowledge of the system through the collusion of insiders is a major benefit to outsiders. Even without deliberate, conscious collusion, the outsider may gain much information from conversation with insiders. Information may be available in public documents. Finally, an adversary can benefit from general knowledge of commercial security practices and hardware. The analyst should be cautious in assuming that any aspect of the physical protection system would not be known to an adversary.

The level of the adversary's motivation seems likely to be high. An attack on a nuclear facility is an unconventional act associated with great hazards. It seems plausible that an unusually strong motivation would be required to initiate the attack. To the extent that deterrence to initiating an attack is high, once an attack has begun, it will be difficult to discourage the adversary from continuing.

The skills useful in the attack can be determined from the analyst's knowledge of the properties of the protection elements. Lacking actual adversaries to examine, it is impossible to catalog their skills. Inferences about the likely size of an attack force may be made by the analyst from a list of special skills that are not likely to be possessed by a single individual.

The speed with which any step in an attack is carried out will vary. For example, where several tests of the same activity have been performed, such as climbing over a particular type of fence, the results are a minimum time, a maximum time, and an average time. When these data are available, the analyst needs a rationale

for the selection of a particular time within the range. In an adversary group not rated for top performance and essentially untrained, speed would vary from one individual to another and from one task to another. The simplest assumption would assign average speed for all tasks. If the group of adversaries is assumed to consist of individuals selected for high potential performance and if they are well-trained, the analyst may assign maximum speed for all tasks.

The capacity to carry tools and weapons should be estimated. For example, the analyst may assume that an adversary on foot can carry an 18-kg (40-pound) load in a hiker's backpack. For a particular attack, the analyst can keep track of the necessary tools and weapons. If the accumulated weight or volume is not portable, the carrying capacity of additional adversaries or vehicles is required.

The tools used by an attacker may include lock picks, ladders, cutting torches, wire cutters, explosives, and many others. Tools may be required to penetrate barriers, to disable detection elements, to jam communications, or to commit sabotage. Weapons, if they are used, range from the very simple to the very powerful. A club, a handgun, an automatic rifle, a shotgun, etc., can be used to combat the response of a physical protection system. These tools can also be used to disable equipment such as lights or cameras.

Variables of the adversary's plan of attack include both choices within his range of capability and within the range of facility characteristics. Choices can be made for the attack among such capabilities and characteristics as environment and weather, the mode and speed of travel, the number of adversaries and their roles and capabilities, the operational state of the facility, the path taken to reach the target(s), the time of day, the tools and weapons carried, and the tactic chosen for each attack task.

Environment and weather can be used by the adversary to his advantage. Wildlife, if able to move through sensor fields, may cause alarms. If these nuisance alarms occur frequently and are difficult to assess, security personnel may become insensitive, making detection of an adversary less likely. Weather may provide an adversary with many opportunities. Heavy rain, snow, fog, or dust can obscure an adversary from observation by assessment elements. Thunder can mask the noise of an explosion. Violent storms may cause a loss of commercial power.

Mode of travel may be by foot, boat, ground vehicle, aircraft, or a combination of these. Speed of travel may be significant after detection of the attack, when a response force is moving as quickly as possible to intercept the attackers.

Number of adversaries is a variable that could allow for a diversionary attack or specialized tasks such as explosive demolition, disablement of electronic equipment, a driver, a battle specialist, etc. A small number of attackers may be preferable where stealth or deceit are the principal tactics used and avoidance of detection is important.

Operational states of the facility include the work shifts, the number of operational employees and guards working each shift, and the locations in a facility where these individuals are situated. Emergency states such as a fire, criticality, a radiation leak, or another abnormal condition may be used to advantage by the adversary and, in fact, the adversary may even cause an emergency.

Several paths to the targets of the attack may exist. The adversary would choose the path which he perceives as being the most advantageous to him. Time of day may also be an important factor. For example, darkness provides cover for attackers, detection systems may not be operated in some locations at all times, and rush hour traffic may degrade response.

FACILITY CHARACTERIZATION

Information must be collected about the site as well as about the adversary. To characterize a facility the analyst must acquire and organize the information needed to perform theft and sabotage target analyses, and to identify other physical protection concerns. The adversary needs to know where to find his targets, how to reach them, what kinds of impediments he must overcome along the way, and what characteristics can be used to his advantage. These are summarized in Table 5. The analyst must know the same information to evaluate the effectiveness of the physical protection system as it interacts with the adversary.

Table 5
Some Important Facility Characteristics

1. Building plans,
2. Climate,
3. Construction types,
4. Environment,
5. Operational states,
6. Paths,
7. Physical protection system,
8. Site layout,
9. Targets,
10. Terrain.

DEFINITION OF OBJECTIVES

The objectives of a physical protection system must be defined prior to development and evaluation of meaningful design concepts. The objectives should relate to

1. Purpose,
2. Performance,
3. Costs, and
4. Impact on other facility systems.

The objectives may be specified, in part, external to the design effort.

Purpose

The principal objective of a physical protection system describes its purpose. Generically, the purpose is to protect nuclear materials from theft or sabotage. Already identified are four essential functions of physical protection (detection, delay, communication, and response) and the defense zone where adversary and physical protection system interact. Analyst and designer must transform the objective of target protection into one or more choices of boundaries for a defense zone: initial boundary where the adversary is first to be detected and final boundary where his attack is to be terminated. This task is performed before the generic physical protection logic trees are examined, using information gathered and organized during threat assessment and facility characterization.

The remaining objectives are more specific to a particular facility. They can be used to guide the selection or evaluation of physical protection elements as the logic trees are examined, event by event.

Performance Objectives

Performance objectives deal with two situations. First, the physical protection system must be highly likely to succeed over a specified range of such attack parameters as threat spectrum, time, weather, target(s), mode(s) of attack, etc. Second, the physical protection system must have predictable performance as attacks increase in severity beyond the specified range of attack parameters. These performance objectives are

1. Protection in depth,
2. System integration,
3. Predictable system performance, and
4. Minimize the impact of the failure of any one subsystem.

To achieve these performance objectives is to provide positive measures in the physical protection system.

"Protection in depth" implies that the performance of a physical protection system should not depend upon only one "line of defense". It refers both to redundant implementation of a function at a given location and to backing up the function at one or more other locations. If the backups are implemented with different technologies, the adversary must have additional knowledge, skills, and tools to defeat the system. If a single barrier cannot sufficiently delay the adversary, "protection in depth" might do so by placing enough barriers in sequence along his path to aggregate the necessary delay. If a single type of sensor cannot be depended upon to respond to an intruding adversary regardless of his method of intrusion, more than one type might be used at a given location. The types preferably would have complementary capabilities. Furthermore, intrusion across a fenced boundary may call for different sensors differently placed than intrusion by tunnelling, or from the air, or by an insider.

System integration is an objective which should enhance system performance. The essential functions must not merely be included in the system but they must also

work together to achieve the desired result. For example, detection of the adversary requires that he be sensed and that his intrusion be properly assessed. The adversary must remain in the vicinity of the sensor long enough after it is activated so that assessment can occur. This requires integration of delay with detection. Furthermore, the barrier which implements delay should not provide cover for the adversary that could thwart effective assessment.

Predictable system performance implies that the assurance of successful protection must not decrease abruptly if the severity of the attack increases slightly. An increase in the severity of the attack might involve use of more powerful and efficient tools, a faster mode of travel, weapons that are more effective, or a greater number of adversaries. The notion of a slight increase in severity is quantitative, not qualitative in nature. For example, if the adversary can choose among three categories of tools--hand tools, power tools, and explosives--switching from power tools to explosives cannot be seen as a small increase in severity merely because it is the next more severe category of tools. The analyst must be aware of how much more energy can be applied to the adversary's tasks by the change of tools and judge the increase in severity by that difference. Predictability of system performance recognizes that system performance will probably degrade somewhat as severity of attack increases; the degradation may even be nonlinear, but the system may not fail utterly to perform its functions if it is placed under a slightly greater stress by the attack.

To minimize the impact of the failure of any one subsystem, contingency plans and redundancy in the designed system are necessary. Furthermore, no function may fail even if one element fails. It is unlikely that a complex system will ever be implemented which does not experience subsystem failure. Causes of subsystem failure in a physical protection system are numerous and can range from environmental factors (which may be expected) to adversary action outside of the threat spectrum used in the system design (not expected). While knowledge of the cause of a subsystem failure is important in an attempt to restore the system to normal operation, it is more important for contingency plans to be provided. These contingency plans will minimize the effects of subsystem failure so that the system continues to operate effectively. Contingency plans may be carried out automatically, e.g., when one piece of equipment fails, redundant equipment automatically begins to perform the function previously performed by the disabled equipment. However, certain subsystem failures may require aid from sources external to the facility in order to minimize the impact of the failure.

Cost Objectives

Cost objectives may be imposed upon a design project. However, they might not be explicit, in which case interest is focused on cost-effectiveness evaluation of alternative designs that meet performance goals. In either case, it is necessary to estimate the cost of each effective system design. While the cost-effectiveness evaluation cannot occur until the design is complete and is not within the scope of this report, cost estimates can be prepared as a design proceeds. The analyst must estimate all system costs:

1. Procurement,
2. Installation,
3. Operation,
4. Maintenance.

Impact Objectives

The last objective is to limit to an acceptable level the impact of the physical protection system on other facility systems. The several facility systems that may be impacted are

1. Material accountability,
2. Material control, and
3. Operations.

The impact of physical protection on material accountability may be neutral or somewhat favorable. The two systems do not interfere, and there are scenarios for which a physical protection system can provide timely detection of theft but material accountability cannot (for example, a theft of a large quantity off-shift when material accountability is not operating). However, material accountability systems should detect repeated diversion of amounts of nuclear material too small to be detected by physical protection systems.

The impact of physical protection on material control may be neutral or require stricter material control. Material control is understood to be the system which authorizes, regulates, and monitors the movement of nuclear material. Whenever the physical protection system intercepts a movement of nuclear material, the propriety of that movement in accordance with material control must be satisfactorily demonstrated. Material control must be sufficiently strict to ensure that it will be very difficult to deceive the physical protection system.

Among several kinds of impact on operations that may occur are changes in

1. Morale,
2. Production costs, and
3. Safety.

An acceptable level of impact on operations should be minimal, since the effects of implementing physical protection can be adverse. Perhaps morale could be favorably impacted if the benefits to society from enhancing the security of nuclear materials are explained; this must offset a tendency to resent an implied distrust of facility employees.

Physical protection is an overhead item, so it inherently adds to the cost of the facility's product. Examples are time consuming, non-productive physical protection measures such as access control and searches for contraband. Economic forces will drive system design to achieve a mandatory level of physical protection as inexpensively as possible.

Safety can conflict with physical protection, as when a real fire or release of radioactivity requires prompt evacuation of a building, but a hoax fire or radioactivity alarm could be used by an adversary to cover his escape with stolen nuclear material. Mandatory safety regulations cannot be arbitrarily overridden by a physical protection system. Instead, the physical protection system must conform to safety regulations, though this might not preclude changes of traditional safety procedures for others that are equally effective but more nearly compatible with physical protection.

DEFINE THE GENERAL PROBLEM

The general problem is defined by establishing the threat spectrum, site attributes, and system objectives.

Threat spectrum must be assigned an upper bound for the purpose of the design, whether the bound is derived from threat analysis or is arbitrarily assumed for lack of predictive information.

Site attributes contribute to defining a general design/analysis problem by establishing the physical context in which the physical protection system must function.

System objectives are needed input for application of the zone concept. Where should first detection of a particular type of threat occur? How far toward the adversary's target or escape should the threat be allowed to proceed? Insiders and outsiders, theft and sabotage all require consideration.

From the system objectives, derive the corresponding defense zones. "Boundaries" are definitive characteristics of zones. The two boundaries, "initial" (first detection) and "final" (termination of attack) must be selected for system objectives to be changed into a useful zone concept.

SELECT A SPECIFIC PROBLEM

To select a specific problem, select one zone to study from all the zones that might be established. In general, several logic trees are required to detail the interactions between the adversary and the physical protection system within one zone. The set of logic trees relevant to a zone can be classified by action (penetrate a boundary, cross an area, enter a building, acquire special nuclear materials, or cause a release) and by tactics (deceit, force, or stealth).

There is a relationship between particular tactics and particular functions. Delay is examined on the force logic trees. Detection is examined on the stealth and/or deceit logic trees. Communication and response are related to the event "Defeat Reinforcements" on any logic tree.

Narrow the problem further by selecting one logic tree to study from among all the trees relevant to one zone. Each logic tree is comprised of many events.

Narrow the problem still further by examining one event in the tree.

DEVELOP OR MODIFY PPS CONCEPTS

Make a list of any physical protection elements which might block an adversary from accomplishing the event. The design should proceed to another event and potentially effective physical protection elements should be listed for the event. This process is continued until all primary events of the logic tree have been considered.

The designer makes a selection of these listed physical protection elements that can be expected to be positive measures, preventing the adversary from accomplishing the event. The designer hopes to achieve a cost-effective system not merely by choosing economical elements from the list for each event but also by taking advantage of redundancy among the lists of elements for all events of the logic tree and taking advantage of the logic of the tree. The adversary can be prevented from accomplishing any event that is the output of an AND gate by preventing him from accomplishing any one event that is an input to the AND gate. Thus a designer can choose among all the element lists associated with inputs to an AND gate for a few that are most cost-effective. More than one element should be chosen to provide a truly positive measure having defense-in-depth and reliability. The attack scenario influences the decision about which elements constitute a positive measure.

ANALYZE

Using the logic trees to evaluate a system is a logically simple procedure. The difficult task for the analyst is deciding whether the design of the physical protection system has positive measures that can prevent an adversary from accomplishing a particular event. Making that decision is beyond the scope of this report. The logical evaluation is presented.

Every event in the generic logic trees describes an action which an adversary must perform to achieve the end event of the tree. Qualitatively evaluate each primary event in the tree. The important question is, "Can the adversary accomplish the event?" The remaining analysis is done quickly and follows simple rules. Examine all events that input to a gate. If the gate is an OR gate, the adversary need only accomplish one of the input events to accomplish the event generated by the OR gate. If the gate is an AND gate, the adversary must accomplish every input event to accomplish the event generated by the AND gate. To keep track of the adversary's accomplishments and failures, mark each event which cannot be accomplished. For example, place an "X" or a "NO" adjacent to each unperformable event. When all events at the bottom level of the tree have been evaluated, all the necessary information has been generated to apply the logical rules to the gates at the next higher level of the tree. Complete one level before moving up to a higher level. Continue until the gate which generates the end event has been evaluated. The process is illustrated in Figure 23 for the logic tree STEALTH-BOUNDARY.

The result is a qualitative evaluation that the adversary can defeat the boundary by stealth. This is indicated by the progression of "yes" conclusions up to the end event S-BOUNDARY.

If, after analysis, the system is evaluated as not adequately effective because some measures are found not to be positive, additional physical protection elements must be placed on the lists and a new design selection must be made to constitute a positive measure. Then evaluate the design again.

When the positive nature of the measures and the effectiveness of the system for one logic tree are confirmed, the design must proceed to another tree by way of selecting another function. The analysis must proceed through each set of generic logic trees needed to describe the interaction in the zone between the adversary and the physical protection system until the adversary is thwarted for all tactics. Then choose another specific problem: choose another adversary from the threat spectrum (look at a different number of outsiders, or look at outsiders differently armed or equipped, etc.). After the threat spectrum has been well sampled, choose another zone. If the adversary is not stopped, the design of the physical protection system is not adequate. The only resort is to question the performance goals from which the zones were initially derived. Conversely, if the adversary's attack is halted within the zone, the design of the physical protection system is adequate (although not necessarily optimal).

ANALYSIS TECHNIQUE EXAMPLES

Define the General Problem

No examples are given of defining the general problem because the scope of this activity is too large to be demonstrated in a few words.

Select a Specific Adversary

To demonstrate the second part of the analysis technique, a particular adversary is selected from the threat spectrum. In this instance, the choice has been made arbitrarily to make the example simple. Let the adversary be a single outsider whose goal is sabotage of a nuclear power reactor that would cause an unacceptable release of nuclear material beyond the site boundary. Assume that the adversary will use stealth tactics in his attack. Also assume that he is well-trained in methods of defeating conventional industrial security systems and is competent in the use of explosives to sabotage equipment.

Select a Specific Zone

Given the site depicted in Figure 19, assume that the zone is a boundary region closely confined to the site perimeter, as depicted in Figure 20. The perimeter is marked by a single fence and one portal location at which there are separate features for vehicle and pedestrian access to and from the site. The objective of this zone is to prevent any adversary from penetrating the fence or portal. In other words, the adversary is not to be allowed to enter the power reactor site.

Select a Specific Logic Tree

For the zone selected, only logic trees for penetration of a boundary need to be analyzed. Three generic logic trees are applicable for the thin, singly fenced zone: DECEIT-BOUNDARY, FORCE-BOUNDARY, and STEALTH-BOUNDARY. All three trees should be analyzed because an adversary is free to use whichever tactic seems to him most advantageous. As a minimum, the stealth and deceit trees would be used to evaluate the detection function, and the force tree would be used to evaluate the delay function. Only the evaluation of detection against stealth tactics is presented to illustrate the method. Figure 21 is the simplified generic logic tree STEALTH-BOUNDARY, which describes how the adversary might penetrate the boundary (in this example, the zone) by stealth. S-BOUNDARY is the same event as DET-STEALTH in Figure 17.

Figure 19. An Hypothetical Power Reactor Site

Figure 20. Example of a Zone

Fitting a Generic Logic Tree to a Particular Facility

The design of a physical protection system for a particular facility will not, in general, have all the elements implied by the generic logic trees. Before the facility can be analyzed, the tree must be modified to accurately describe the facility and its physical protection system. Using Figure 21, assume that the physical protection system design being analyzed includes only one fence. Keep event S3-1 (outer fence) but delete (cross off) events S3-4 (inner fence) and S3-2 (area between fences). Assume that no provision has been made in the design to delay underground or air attacks and that the single fence is the only barrier in the design. Delete S3-3 (other barriers). The result is that AND gate S2-2 has only two inputs, S3-1 (outer fence) and SX3-5 (defeat or bypass sensors). Since the initial boundary of a zone is the concern in this case, previous detection is not

Figure 21. STEALTH-BOUNDARY, Simplified

assumed. Also, delete S1-1 (avoid or confront reinforcements). Figure 22 is the modified STEALTH-BOUNDARY logic tree. Modify similarly each logic tree needed to analyze the zone.

Describing or Designing the System

Before a logic tree can be analyzed to see if a physical protection system can prevent an adversary from accomplishing the end event, it is necessary to note the elements on the logic tree adjacent to each event which they might prevent. Figure 22 shows an example of detection elements that could act at the singly fenced boundary of the power reactor site. The selection, mixing manpower and relatively simple technology, is representative of basic industrial security. The single fence is described only as "chain link" (S3-1). At the portal (S2-1), it is assumed that guards must activate a turnstile for access by pedestrians. Access by vehicles has been omitted in this example. The fence along the perimeter of the site is patrolled by guards (S2-3) approximately every 30 minutes. If guards see an intrusion, they can report it by radio (walkie-talkie, S2-4). Site personnel are trained to report suspicious activity and alarm boxes are provided for signalling (S1-3). Finally, no sensing hardware is installed along the fence (SX3-5).

It is possible for this procedure to be used either by an analyst, associating actual or planned physical protection elements with a logic tree, or by a designer, speculating about what elements could prevent an adversary from accomplishing events. In a design process, the association of physical protection elements and events produces lists of possible parts of a physical protection system. The designer might then choose which elements are most cost-effective to define the system.

Evaluating a System

For the physical protection elements given as an example in Figure 22, level 3 (the bottom level of the tree) is where evaluation begins. The results of evaluation are shown in Figure 23. Arbitrarily, the primary events will be evaluated from left to right, so event S3-1 is examined first.

S3-1: Defeat (outer) fence -- over, under, or through. Recall that this example has only one fence, so "outer" fence is an irrelevant description. Examination of the Barrier Technology Handbook (SAND77-0777, see Tables 3.6-I, 3.6-II, and 3.6-III therein) will show that a chain link fence, no matter how elaborated with barbed wire or tape, can be penetrated by going through it with aids as simple as gloves, boltcutters, wirecutters, or some combination of these, in approximately a half minute or less. The fence can be penetrated in less than a half minute by going under it with the aid of one or two additional adversaries using gloves or one or two long (3-metre) pieces of pipe. The fence can be penetrated in less than a half minute by going over it with the aid of gloves, hooks, carpet, or some combination of these. An adversary can accomplish event S3-1 quickly and with only a minor burden of tools.

SX3-5: Defeat or bypass detection system. There is no sensing hardware along the fence in the example, so the event is trivial, and any adversary can "accomplish" it.

Figure 22. Generic Logic Tree Fitted to Site Boundary

Figure 23. Evaluating a Generic Logic Tree

An adversary can accomplish both S3-1 and SX3-5, so he can accomplish S2-2 which is generated from them by an AND gate.

Next the analyst evaluates the primary events at level 2 of the logic tree.

S2-1: Defeat personnel entrance -- gate, portal, or building -- undetected. This event is evaluated to demonstrate the technique, but the analyst should be aware that the previous evaluation of S2-2 has made it unnecessary. Since S2-1 and S2-2 are inputs of an OR gate that generates event S1-2, and because analysis has already shown that an adversary can easily accomplish S2-2, it follows that the adversary can easily accomplish S1-2 whether or not he can accomplish S2-1.

An adversary using stealth tactics to penetrate a gate or portal intends not to be detected. The adversary will try to stay out of range of any sensing elements or to tamper with them so no alarm is generated as he penetrates the gate or portal. In this example, guards at the single entrance must activate a turnstile to allow entrance or exit. The adversary's problem is to pass the turnstile without being detected by a guard. Assume that the guards can have the turnstile continuously under visual and aural observation, and assume that the adversary must either mechanically alter the turnstile or climb over it. Mechanical alteration of the turnstile would involve partially dismantling it, probably with the aid of power tools. If seen or heard, either action would be self-evidently improper. Though supporting data is lacking, it seems that guards would be effective detectors in the situation visualized in this example. Thus, the adversary probably could not accomplish event S2-1, (i.e., could not get past the turnstile by stealth, undetected).

S2-3: Avoid detection by guards -- patrol, stationary, etc. In this example, a patrol of one guard completes a circuit of the single fence approximately every 30 minutes. The analyst should make use of the information gathered for evaluation of S3-1, penetration of the single fence. No matter how the adversary chooses to get across the fence, he can do it in a half minute or less. By inspection of Figure 19, it appears that the adversary can be out of sight of the patrol guard for approximately 15 minutes, assuming that the fence crossing is made where the fence is nearest the reactor building and on the side opposite the entrance gate or portal. It seems reasonable to conclude that the adversary can approach the fence, use a half minute for the crossing, and reach cover among the reactor structures before the patrol guard can see the area where the crossing was made. The adversary can accomplish S2-3.

S2-4: Disable guards without alarm sounded. The guards have walkie-talkie radios for communication of alarms. There are guards stationed at the gate or portal and there is one guard on patrol. An alert adversary should be able to avoid the patrol guard as described for event S2-3. An intelligent adversary should be able to avoid the gate guards merely by keeping cover between himself and them. If the adversary accidentally confronts a guard, no matter who is more surprised, it seems that the guard can sound some sort of warning over his radio. Thus the adversary cannot accomplish S2-4.

An adversary can accomplish S2-3 but not S2-4. These two events generate event S1-4 through an OR gate. Thus S1-4 can be accomplished because S2-3 can be accomplished, regardless of whether S2-4 can be accomplished.

Next evaluate the primary events at level 1 of the logic tree.

S1-3: Avoid or confront area personnel undetected. Area personnel are workers who have operational or administrative duties as opposed to security duties. They are trained, however, to look for possible intruders and to report possible intrusions by using one of the alarm boxes placed near the fence (and throughout the nuclear facility). Assuming that the adversary can choose a place and time for crossing the fence that will not inevitably bring him into close contact with area personnel, and allowing the adversary time to hide until any personnel who might come near have departed, it seems plausible that detection by area personnel can be avoided. If an accidental confrontation occurs, the employee has a relatively modest chance of being near enough to an alarm box to sound an alarm unless he overpowers or escapes from the adversary. An adversary might, under particular circumstances, be detected. But an alert, intelligent adversary seems able usually to accomplish S1-3 by avoiding area personnel. The analyst may annotate this event with "MAYBE" or "YES?" as a reminder of the relatively large element of chance in the outcome of the event, but the analysis will treat the event as if it were simply annotated with "YES." In other words, the burden of proof of effectiveness lies with the physical protection system.

Since S1-3 was the only primary event on level 1 of the logic tree, the analyst now evaluates the end event S-BOUNDARY. Events S1-2, S1-3, and S1-4 all can be accomplished by the adversary, and this satisfies the requirement imposed by the AND gate for the accomplishment of S-BOUNDARY. In this example, the logic of the tree acting on the evaluations of the primary events leads to the conclusion that the adversary can defeat the protected boundary by stealth undetected by the physical protection system.

It is necessary to similarly analyze FORCE-BOUNDARY and DECEIT-BOUNDARY since the adversary has the option of using any tactic. Only if all adversary tactics fail has the physical protection system succeeded.

APPENDIX A
Abridged Generic Physical Protection Logic Trees

ABRIDGED GENERIC PHYSICAL PROTECTION

"AREA" GENERIC LOGIC TREES

There are three generic logic trees: one each for crossing the area by stealth, force, and deceit tactics. The primary events of each tree can be divided into two groups: (1) how the adversary gets across the area and (2) how the adversary remains undetected (stealth and deceit trees) or overcomes any opposition that he encounters while he traverses the area.

Physically, the terrain to be crossed is a distributed barrier whose parameters include, at least, its extent (length of path to be travelled) and the difficulty of travel (rate of travel along the path). Thus, the primary event for traversing the area relates to the distributed barrier that must be overcome.

One question to ask in a qualitative evaluation of the logic tree is, "Can the adversary overcome the barrier(s) to crossing the area?" The specific terrain is important, but terrain suitable for efficient site operations will require only ordinary skills and equipment of the adversary. For the stealth and deceit trees a second question is, "Is it likely that the adversary can avoid, disable, or deceive the detection elements without an alarm being generated?" For the force tree a second question is, "Is it likely that the adversary can overcome any opposition that he encounters?"

If a quantitative evaluation is needed, one question is, "How much time will the adversary need to overcome the distributed barrier?" This time, the delay provided by the barrier is a function of the length of the path travelled and the speed with which the terrain can be travelled using the means assumed for the adversary. The other quantitative question is, "What is the probability that the adversary will be detected as he traverses the area?"

STEALTH-AREA

Figure A-1 shows a simplified version of the generic logic tree, STEALTH-AREA. There are 6 primary events (S1-1, S1-3, S1-4, SX1-5, S2-1, S2-2). These can be divided into two groups. One group concerns the adversary's need to get across the area (S1-1). The other group concerns the adversary's need to remain undetected while he traverses the area (S1-3, S1-4, SX1-5, S2-1, S2-2).

The logic tree assumes that the area is homogeneous. Thus, there is one basic event (S1-1) for traversing an area. The event does not describe the nature of the terrain. It is the analyst's job to characterize the terrain from site-specific information. If the terrain is not virtually homogeneous, adjacent areas can be defined, each of which has essentially homogeneous characteristics.

Figure A-1. STEALTH-AREA Logic Tree

Two kinds of elements detect area traversals. One kind surveys the area from a fixed position (SX1-5, S2-1, S2-2). Guards stationed in observation towers (S2-1, S2-2) and radar (SX1-5) are examples.

The second kind of element is mobile within the area (S1-3, S1-4, S2-1, S2-2). Guards on patrol are one example (S2-1, S2-2).

Operations personnel may be traversing the area at the same time and in the same region as the adversary, and they may see him (S1-4). If the population of the site is large, so all workers are not known to one another, and if the adversary is dressed within the expected variation for site workers, he should not arouse suspicion. Especially if there is cover nearby, the adversary may be able to avoid a direct meeting with an employee (S1-4) which could lead to a confrontation over credentials which the stealthy adversary is presumed not to have.

Reinforcements for the security force (S1-3) would be called only after detection. The time between notification of the security force and its arrival might be long enough to prevent the force from intercepting the adversary during the area traversal that gave rise to the detection. However, this event might be relevant given detection at a previous boundary or area.

Having examined all primary events on the simplified logic tree, note that the logic by which they generate the end event is the same as for the STEALTH-BOUNDARY tree. The adversary must traverse the area and he must avoid detection while doing so. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by AND gate S-AREA. The input for area traversal comes from event S1-1. All four other inputs (S1-2, S1-3, S1-4, SX1-5) supply requirements for avoiding detection.

One other development appears on the tree. Event S1-2, "Avoid or confront guards undetected" states an option. The necessary logic is an OR gate, S1-2, with inputs S2-1 and S2-2. This same sort of option is implied for S1-3 and S1-4, both undeveloped events. Their developments would have the same logical form as the development of S1-2.

FORCE-AREA

Figure A-2 shows a simplified version of the generic logic tree, FORCE-AREA. There are five primary events (F1-1, F1-3, F1-4, F2-1, F2-2). These can be divided into two groups. One group concerns the adversary's need to traverse the area (F1-1). The other group concerns the adversary's need to overcome any opposition that he encounters while he traverses the area (F1-3, F1-4, F2-1, F2-2).

Every event but one on STEALTH-AREA has a counterpart on FORCE-AREA. The exception is SX1-5, "Defeat or bypass detection system." By definition, when using the force tactic the adversary expects to be detected, so the FORCE trees have no events that require the adversary to take action against the detection system.

Figure A-2. FORCE-AREA Logic Tree

DECEIT-AREA

Figures A-3 and A-4 show a simplified version of the generic logic tree, DECEIT-AREA. There are 16 primary events (D1-1, DX1-3, DX1-6, DX2-1, DX2-2, DX2-3, DX2-6, DX2-7, DX2-8, DX3-1, DX3-2, DX3-4, DX3-5, DX3-6, DX4-1, DX4-2). They can be divided into two groups. One group concerns the adversary's need to get across the area (D1-1, DX4-1, DX4-2). The second group concerns the adversary's need to remain undetected while he traverses the area (DX1-3, DX1-6, DX2-1, DX2-2, DX2-3, DX2-6, DX2-7, DX2-8, DX3-1, DX3-2, DX3-4, DX3-5, DX3-6).

The logic tree assumes that the area is homogeneous. Thus, there is one basic event (D1-1) for traversing an area. The event does not describe the nature of the terrain. It is the analyst's job to characterize the terrain from site-specific information. If the terrain is not virtually homogeneous, adjacent areas can be defined, each of which has essentially homogeneous characteristics.

There is also the possibility that an additional adversary might take part in a scenario, making a two-man adversary team to defeat a two-man rule. Basic event DX4-1 specifies that the second man of the two man team is an adversary. Undeveloped event DX4-2 is the defeat of the area by the second man using deceit. The analyst is told to review the logic tree D-AREA for the second man.

Detection of area traversal by an adversary using deceit seems unlikely. It is barely conceivable that the adversary might arouse suspicion of area personnel, or that spot checks of persons in the area might be made, either case leading to a recheck of the adversary's identity and authorization to be in the area. The adversary's need to defeat detection by area personnel is covered by developed event DX1-3. The events related to defeat of an identity credential check (DX2-1, DX2-2, DX2-3) are identical to those on the logic tree DECEIT-BOUNDARY. The events related to defeat of an authorization check (DX2-6, DX2-7, DX2-8) are analogous to those on the logic tree DECEIT-BOUNDARY. Though there is no obvious need or mechanism to initiate a two man rule within an area, it would be necessary to maintain one initiated at a previous boundary. Consequently, the subtree covering the adversary's need to traverse the area despite the two-man rule is duplicated from the logic tree DECEIT-BOUNDARY. The primary events that concern detection avoidance are DX3-1, DX3-2, DX3-4, DX3-5, and DX3-6. Finally, there is a possibility that the adversary would need to avoid, deceive, or defeat a response to detection that occurred during the area traversal or at an earlier time in the attack (DX1-6, an undeveloped event).

Having examined all primary events on the simplified logic tree, note that the logic by which they generate the end event is the same as for the STEALTH-BOUNDARY tree. The adversary must traverse the area and he must avoid detection while doing so. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental statement is made by the AND gate D-AREA. The input for area traversal comes from event D1-1. All other inputs (DX1-2, DX1-3, DX1-4, DX1-5, DX1-6) supply requirements for avoiding detection.

Figure A-3. DECEIT-AREA Logic Tree

Figure A-4. DECEIT-AREA, Two-Man Rule Logic Tree

The types of identity credentials which an adversary might use (DX2-1, DX2-2, DX2-3), expressed in terms of the degree of the adversary's detectability, complete the development of DX1-2 as inputs to an OR gate.

The types of authorization which an adversary might have (DX2-6, DX2-7, DX2-8), expressed in terms of the degree of the adversary's detectability, complete the development of DX1-5 as inputs to an OR gate.

The adversary's options for defeating a two-man rule (DX3-1, DX3-2, DX3-3, DX3-4, DX3-5, DX3-6) constitute the development of DX1-4 as inputs to OR gates. For ease of reading this portion of the logic tree, DX3-1, DX3-2, and DX3-3 are grouped as inputs to OR gate DX2-4. Event DX2-4 merely labels its inputs as all dealing with options in which a second man does traverse the area with the adversary. Events DX3-4, DX3-5, and DX3-6 are grouped as inputs to OR gate DX2-5. Event DX2-5 merely labels its inputs as all dealing with options in which a second man does not traverse the area with the adversary. The two "label" events, DX2-4 and DX2-5, are inputs to OR gate DX1-4. Finally, DX4-1 and DX4-2 are pseudo-events (equivalent to comments) pertaining to event DX3-3. They remind the analyst of two concurrently relevant things: that the second man can also be an adversary and that this additional adversary must be analyzed using the full tree, D-AREA. So, DX4-1 and DX4-2 are inputs to AND gate DX3-3.

"BUILDING" GENERIC LOGIC TREES

There are two generic logic trees: one each for entering or leaving a building by stealth or force. The primary events of each tree can be divided into two groups: (1) how the adversary enters or leaves the building, and (2) how the adversary remains undetected (stealth tree) or overcomes any opposition that he encounters while entering or leaving the building.

One question to ask in a qualitative evaluation of the logic tree is, "Can the adversary overcome the barrier(s) to entering or leaving the building?" For the stealth tree a second question is, "Is it likely that the adversary can avoid or disable the detection elements without an alarm being generated?" For the force tree a second question is, "Is it likely that the adversary can overcome any opposition that he encounters?"

If a quantitative evaluation is needed, one question is, "How much time will the adversary need to overcome the barrier(s) to entering or leaving the building?" The other quantitative question is, "What is the probability that the adversary will be detected as he enters or leaves the building?"

STEALTH-BUILDING

Figure A-5 shows a simplified version of the generic logic tree, STEALTH-BUILDING. There are 10 primary events (S1-2, S1-4, S2-1, S2-2, S2-4, S2-5, S3-1, SX3-2, S3-3, SX3-4). These can be divided into two groups. One group concerns the adversary's need to get into or out of the building (S2-1, S2-2, S3-1, S3-3). The

Figure A-5. STEALTH-BUILDING Logic Tree

other group concerns the adversary's need to remain undetected while entering or leaving the building (S1-2, S1-4, S2-4, S2-5, SX3-2, SX3-4).

The logic tree assumes the building, as a boundary, has two parts. In one part, entry or exit is accomplished normally, i.e., through a personnel or equipment entrance, a safety exit, etc. (see event S2-2); in the other, entry and exit are prohibited, i.e., everywhere other than a personnel or equipment entrance, safety exit, etc. (see events S2-1, S3-1, S3-3). These two parts of the boundary should present different problems to the adversary.

A few, but not all, possible types of normal entrances are named in event S2-2. It is the analyst's job to supply these elements from the design which he is evaluating. However, S2-2 is a developed event; it is further developed on the complete generic logic tree, STEALTH-BUILDING. That development is ignored in this discussion.

There are entrances that are not normally used by personnel but which could be penetrated by the adversary. Some of these possibilities are named in event S2-1 (service inlets: vents, windows, utility tunnels, sewers, etc.). It is the analyst's job to supply these elements from the design which he is evaluating. However, S2-1 is a developed event; it is further developed on the complete generic logic tree, STEALTH-BUILDING. That development is ignored in this discussion.

The other means of entering or leaving a building that is unconventional is to penetrate the structure of the building (see event S3-3). The structure may be protected by an overburden of earth or other material (see event S3-1). It is the analyst's job to supply from the design which he is evaluating, the details of overburden composition and penetrability and of building structural features and penetrability.

Two kinds of elements detect entering or leaving a building. One kind is associated with the building itself, its entrances and structure (SX3-2, SX3-4). No examples are named on the simplified logic tree.

A second kind of element is mobile and operates anywhere along the periphery of the building, either inside or outside (S1-2, S1-4, S2-4, S2-5). Guards on patrol or stationed in observation towers are one example (S2-4, S2-5). These would be a trained part of the physical protection system. If they alone could not be positive measures for detection, they may reinforce the other kinds of detection elements to produce positive measures.

The two events that name guards as detection elements list two ways that an adversary may not be detected. He can avoid being seen by the guards (S2-4), or, if he is seen, he may be able to prevent the guards from sounding an alarm (S2-5). While the latter method of avoiding detection may be forceful rather than stealthy, it represents an action required of the adversary if he is to continue his attack by stealth, undetected, after he accidentally confronts a guard. In general, the adversary should be able to conceal himself and observe the movement of the patrol.

The adversary could wait until the patrol leaves the vicinity of the place where the building is to be attacked before beginning the attack. It may be difficult for the adversary to know whether or not he is being seen from an observation tower or to prevent the sounding of an alarm if he knows that he has been seen.

Operations personnel may be nearby when the adversary makes his attempt to penetrate the building and may see a suspicious action (S1-4). The adversary may have difficulty avoiding operations personnel: his attention may be concentrated on the physical work of his penetration attempt, and the building itself (as well as any other buildings that might be nearby) can expose the adversary and operations personnel to one another suddenly and at relatively close quarters. Confrontation would be an unintended complication of an attack by stealth, and it might increase the chance of being seen by a guard in an observation tower.

Reinforcements for the security force (S1-2) would be called only after detection. The time between notification of the security force and its arrival should be carefully compared with the expected task time for penetration that remains after detection of the penetration. Whether the security force could intercept the adversary during the penetration attempt is strongly dependent on site details and the adversary's scenario. This event may be meaningful with respect to penetrating a building after detection had previously occurred.

Having examined all primary events on the simplified logic tree, the logic by which they generate the end event is examined next. The adversary must penetrate the building and he must avoid detection while doing so. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by AND gate S-BLDG. The input for penetrating the building comes from event S1-1. All three other inputs (S1-2, S1-3, S1-4) supply requirements for avoiding detection by the elements that can operate anywhere along the periphery of the building, regardless of where the penetration is made. The elements that detect only at entrances, normal or unusual, or only at building structure away from entrances must be associated with those optional locations for penetrating the building.

The operational penetration locations are inputs S2-1, S2-2, and S2-3 to OR gate S1-1. Penetrating the building through a normal entrance or exit (S2-2) is a developed primary event. Penetrating the building through one of the service inlets (e.g., vents, windows, utility tunnels, sewers) is also a developed primary event (S2-1). But penetrating the building away from a normal entrance or service inlet (S2-3) is generated by an AND gate which repeats the fundamental logical statement of the logic tree. Penetrating the building away from a normal entrance or service inlet requires that two basic events (S3-1, S3-3) be performed. These two events are inputs to AND gate S2-3. Avoiding detection during penetration is represented by two developed events (SX3-2, SX3-4), both of which are inputs to AND gate S2-3.

One other development appears on the tree. Event S1-3, "Avoid or confront guards undetected" states an option. The necessary logic is an OR gate, S1-3, with

inputs S2-4 and S2-5. This same sort of option is implied for S1-2 and S1-4, both developed events. Their developments would have the same logical form as the development of S1-3.

FORCE-BUILDING

Figure A-6 shows a simplified version of the generic logic tree, FORCE-BUILDING. There are eight primary events (F1-2, F1-4, F2-1, F2-2, F2-4, F2-5, F3-1, F3-2). These can be divided into two groups. One group concerns the adversary's need to penetrate the building (F2-1, F2-2, F3-1, F3-2). The other group concerns the adversary's need to overcome any opposition that he encounters while penetrating the building (F1-2, F1-4, F2-4, F2-5). Every event but two on STEALTH-BUILDING has a counterpart on FORCE-BUILDING. The exceptions are SX3-2, "Defeat or bypass detection system of overburden," and SX3-4, "Defeat or bypass structure detection system." By definition, when using the force tactic the adversary expects to be detected, so the FORCE trees have no events that require the adversary to take action against the detection system.

"ACQUIRE SNM" GENERIC LOGIC TREES

There are three generic logic trees titled ACQUIRE SNM: one each for acquiring SNM by stealth, force, and deceit tactics. The primary events of each tree can be divided into two groups: (1) how the adversary gets special nuclear material into his possession and (2) how the adversary remains undetected (stealth or deceit trees) or overcomes any opposition that he encounters while the SNM is acquired.

When using any ACQUIRE SNM tree it is assumed that the adversary is almost in the presence of the SNM. If the SNM is stored in a vault, the adversary has arrived at the vault. If the SNM is in a pipe, the adversary is in a place where he has access to the pipe. If the SNM is in a process line, the adversary is in the presence of the process line, for example, at a glove box containing SNM. Thus the primary events for acquiring SNM relate to barriers that enclose the SNM in close proximity or that have to do with properties of the SNM itself.

One question to ask in a qualitative evaluation of the logic tree is, "Can the adversary overcome the barrier(s)?" For stealth and deceit trees a second question is, "Is it likely that the adversary can avoid, disable, or deceive the detection elements without an alarm being generated?" For the force tree a second question is, "Is it likely that the adversary can overcome any opposition that he encounters?"

If a quantitative evaluation is needed, one question is, "How much time will the adversary need to acquire SNM?" The other quantitative question is "What is the probability that the adversary will be detected as he acquires SNM?"

Figure A-6. FORCE-BUILDING Tree

STEALTH-ACQUIRE SNM

Figure A-7 shows a simplified version of the generic logic tree, STEALTH-ACQUIRE SNM. There are 10 primary events (S1-1, S1-3, S1-4, S1-5, SX1-6, S2-1, S2-2, SX3-1, SX3-2, SX3-3). These can be divided into two groups. One group concerns the adversary's need to get the special nuclear material into his possession (S1-1, S2-1, S2-2). The other group concerns the adversary's need to remain undetected while acquiring the SNM (S1-3, S1-4, S1-5, SX1-6, SX3-1, SX3-2, SX3-3).

The logic tree assumes that acquiring SNM is a single process having as many as three steps (see events S1-1, S2-1, S2-2). Each step is a primary event, and the description of each step includes examples of physical protection system elements and site specific characteristics that must be supplied by the analyst from the design which he is evaluating.

Locating and recognizing the SNM is the adversary's first step, S1-1. Assuming that the adversary has information about his target, this is a trivial task. The analyst must take care not to double count the task time with those of other events on STEALTH-ACQUIRE SNM and other logic trees that contribute to the same result as basic event S1-1.

Defeating the constraints imposed by the storage location of the SNM is the adversary's second step, S2-1. This means penetrating whatever physical protection barriers surround the storage space. For example, the SNM may be stored in a vault which the adversary must enter. SNM may be flowing through a pipe which the adversary must tap, and the pipe may be enclosed in a chase which must be penetrated. SNM may be in a process line, for example, enclosed by a glove box to which the adversary would need access. S2-1 is an undeveloped event.

Collecting the SNM is the adversary's third step, S2-1. This means selecting the SNM to be taken and repackaging it as necessary. Several of the factors that might influence SNM collection are listed in the event description. Composition of the SNM, for example a liquid, a metal, a powder, will affect the kind of package in which it might have been stored or in which the adversary might wish to store it for removal from the site. The size, weight, and shape of the container(s) in which the site stores SNM might be inconvenient for an adversary to pick up and carry with him. If repackaging is necessary, additional time is necessary for the task, and possibly special packages must have been acquired somewhere and carried to the location of the SNM. The analyst must decide whether these target characteristics are an effective impediment to the adversary. Because of the variety of possible SNM targets, their characteristics, and the variety of the adversary's scenarios, S2-2 is an undeveloped event.

Three kinds of elements detect acquisition of SNM. One kind senses properties of SNM itself and is located permanently in the immediate vicinity of SNM with the purpose of detecting unauthorized movement of SNM (SX3-1, SX3-2, SX3-3). No examples are named on the simplified logic tree.

Figure A-7. STEALTH-ACQUIRE SNM Logic Tree

The second kind of element uses fixed sensors to signal the penetration of an unauthorized person into an area where SNM is being processed or stored (S1-6). No examples are named on the simplified logic tree.

The third kind of element operates anywhere within the material access area (S1-3, S1-4, S1-5). Guards on patrol are one example (S1-5). These would be trained as part of the physical protection system. If they alone could not be positive measures for detection, they might reinforce the other kinds of detection elements to produce positive measures.

The event S1-4 that names patrol guards as detection elements lists two ways that an adversary may not be detected. He can avoid being seen by the guards, or, if he is seen, he may be able to prevent the guards from sounding an alarm. While the latter method of avoiding detection may be forceful rather than stealthy, it represents an action required of the adversary if he is to continue his attack by stealth, undetected, after he accidentally confronts a guard. In general, the adversary may be able to hide until the patrol guards have passed and then have use of the period until the patrol is repeated to acquire SNM.

Operations personnel may be nearby when the adversary acquires SNM and see his activity (S1-5). Depending upon the work schedule of a particular site, the adversary may be confident of avoiding accidental observation. Confrontation would be an unintended complication of an attack by stealth, and it may increase the chance of being observed by other operations personnel or patrol guards.

Reinforcements for the security force (S1-3) would be called only after detection. The time between notification of the security force and its arrival might be long enough to prevent the force from intercepting the adversary during the acquisition of SNM that gave rise to the detection, but one cannot generalize about this. Thus, this event may have relevance during acquisition of SNM. The analyst must carefully consider the scenario and the physical protection system to decide this question. This event may instead be meaningful with respect to detection during a prior step of the scenario such as crossing a boundary, traversing an area, or entering a building.

Having examined all primary events on the simplified logic tree, the logic by which they generate the end event is examined next. The adversary must acquire SNM and he must avoid detection while doing so. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by AND gate S-ACQUIRE. The input for acquiring SNM comes from events S1-1 and S1-2. All four other inputs (S1-3, S1-4, S1-5, SX1-6) supply requirements for avoiding detection.

Event S1-2 is logically redundant, being merely a collective label for its inputs (S2-1, S2-2, SX2-3). Events S2-1 and S2-2 deal with acquiring SNM. Event SX2-3 supplies requirements for avoiding detection of the SNM itself while it is being acquired.

Only one true development appears on the tree. Event SX2-3, "Defeat or bypass SNM monitors" is developed into the three aspects (sensing, communication, and assessment) of a detection system which state the options for causing failure of detection. The necessary logic is an OR gate, SX2-3, with inputs SX3-1, SX3-2, and SX3-3, all basic events.

FORCE-ACQUIRE SNM

Figure A-8 shows a simplified version of the generic logic tree, FORCE-ACQUIRE. There are six primary events (F1-1, F1-3, F1-4, F1-5, F2-1, F2-2). These can be divided into two groups. One group concerns the adversary's need to get the special nuclear material into his possession (F1-1, F2-1, F2-2). The other group concerns the adversary's need to overcome any opposition that he encounters while the SNM is acquired (F1-3, F1-4, F1-5).

Four events on STEALTH-ACQUIRE have no counterparts on FORCE-ACQUIRE. The exceptions are SK1-6, "Defeat or bypass intrusion detection system;" SX3-1, "Defeat or bypass sensors;" SX3-2, "Defeat communication of alarm;" and SX3-3, "Defeat or bypass assessment of alarm." By definition, when using the force tactic the adversary expects to be detected, so the FORCE trees have no events that require the adversary to take action against the detection system.

DECEIT-ACQUIRE SNM

Figures A-9 and A-10 show a simplified version of the generic logic tree, DECEIT-ACQUIRE SNM. There are 20 primary events (D1-1, D1-3, D1-5, D2-1, D2-2, DX2-4, DX2-5, DX3-1, DX3-2, DX3-3, DX3-4, DX3-5, DX3-6, DX3-7, DX3-8, DX3-10, DX3-11, DX3-12, DX4-1, DX4-2). These can be divided into two groups. One group concerns the adversary's need to get the special nuclear material into his possession (D1-1, D2-1, D2-2, DX4-1, DX4-2). The other group concerns the adversary's need to remain undetected while acquiring the SNM (D1-3, D1-5, DX2-4, DX2-5, DX3-1, DX3-2, DX3-3, DX3-4, DX3-5, DX3-6, DX3-7, DX3-8, DX3-10, DX3-11, DX3-12).

The logic tree assumes that acquiring SNM is a single process having as many as three steps (see events, D1-1, D2-1, D2-2). Each step is the exact duplicate of a corresponding step on the logic tree STEALTH-ACQUIRE SNM: D1-1 duplicates S1-1, D2-1 duplicates S2-1, and D2-2 duplicates S2-2. The reader is referred to the section "STEALTH-ACQUIRE SNM" for explanation of these events.

If in immediate proximity to SNM a two-man rule is initiated or continued from prior initiation, the adversary should not be allowed to operate alone. An adversary could try to defeat the physical protection system by having another, collaborating adversary act as the second man of the two-man team (basic event DX4-1). In this case, the second adversary as well as the first must be analyzed for his ability to defeat the logic tree D-ACQUIRE (undeveloped event DX4-2).

Four kinds of elements detect or try to prevent acquisition of SNM. One kind senses properties of SNM itself and is located permanently in the immediate vicinity of SNM with the purpose of detecting unauthorized movement of SNM (DX2-4, DX3-1,

Figure A-8. FORCE-ACQUIRE SNM Logic Tree

Figure A-9. DECEIT-ACQUIRE SNM Logic Tree

Figure A-10. DECEIT-ACQUIRE SNM, Two-Man Rule Logic Tree

DX3-2, DX3-3). Unique to the deceit tactic is the possibility (basic event DX2-4) that the adversary will be able to conduct a normal transaction to acquire SNM and only afterward try to retain unauthorized possession of it. If the adversary will not risk the detection of the SNM that he acquires, he can exploit a failure of the SNM detection system (undeveloped event DX3-1) that he somehow learns about, he can defeat or bypass the SNM detection system (undeveloped event DX3-2), or he might have the collaboration of key personnel of the SNM detection system to either defeat the system for the adversary or ignore its alarms (undeveloped event DX3-3).

A second kind of element is the material accounting system (DX2-5, DX3-4, DX3-5, DX3-6). If the adversary does not need to keep the loss of SNM hidden longer than the reaction time of the material accounting system, he can ignore it in his SNM acquisition scenario (developed event DX2-5). However, if the adversary plans to hide the loss of SNM for an indefinitely long time, he might attempt to spoof the material accounting system either by tampering with the records of the system (undeveloped event DX3-4), or by substitution of other material for the SNM (undeveloped event DX3-5), or perhaps by some other technique (undeveloped event DX3-6).

A third kind of element operates anywhere within the material access area (D1-3, D1-5). The description of events S1-3, S1-4, and S1-5 from STEALTH-ACQUIRE SNM is also appropriate for these deceit events.

The fourth and final kind of element is a two-man rule whose purpose is to prevent unauthorized acquisition of SNM (DX3-7, DX3-8, DX3-10, DX3-11, DX3-12). The subtree covering the adversary's need to traverse the area despite the two-man rule is duplicated from the logic tree DECEIT-BOUNDARY. The primary events that concern detection avoidance are DX3-7, DX3-8, DX3-10, DX3-11, DX3-12.

Having examined all primary events on the simplified logic tree, the logic by which they generate the end event is examined next. The adversary must acquire SNM and he must avoid detection while doing so. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by AND gate D-ACQUIRE. The inputs for acquiring SNM come from events D1-1 and D1-2. All five other inputs (D1-3, D1-4, D1-5, D1-6, D1-7) supply requirements for avoiding detection.

Before SNM can be physically acquired it must be located and recognized (basic event D1-1). This should not be difficult for a well informed adversary, especially an insider. This event essentially is a reference to the prior part of the scenario that brought the adversary into close proximity to the SNM so that it could be "recognized." The analyst must be careful not to double count time to accomplish D1-1 that has already been counted in the analysis of other logic trees.

Event D1-2, "Obtain SNM," is logically redundant, being merely a collective label for its inputs (D2-1, D2-2). Events D2-1 and D2-2 deal with acquiring SNM. They can be regarded as inputs to AND gate D-ACQUIRE.

There are three real developments on the tree, but they contain logical redundancies. The adversary has several options for the defeat of any local SNM detection system: inputs to OR gate DX1-4 are DX2-4 (the SNM detection system accepts the acquisition of SNM as an authorized transaction) and DX2-3 (the SNM detection system fails to detect withdrawal of any SNM). However, event DX2-3 is merely a collective label for events DX3-1, DX3-2, and DX3-3 which are inputs to OR gate DX2-3, but could logically be direct inputs to OR gate DX1-4.

The second development is of the adversary's options to defeat or ignore the material accounting system: inputs to OR gate DX1-6 are DX2-5 (the adversary ignores the material accounting system) and DX2-6 (the adversary spoofs the material accounting system). However, event DX2-6 is merely a label for events DX3-4, DX3-5, and DX3-6 which are inputs to OR gate DX2-6, but could logically be direct inputs to OR gate DX1-6.

The adversary's options for defeating a two-man rule (DX3-7, DX3-8, DX3-9, DX3-10, DX3-11, DX3-12) constitute the development of DX1-7 as inputs to OR gates. For ease of reading this portion of the logic tree DX3-7, DX3-8, and DX3-9 are grouped as inputs to OR gate DX2-7. Event DX2-7 merely labels its inputs as all dealing with options in which a second man does cross the boundary with the adversary. Events DX3-10, DX3-11, and DX3-12 are grouped as inputs to OR gate DX2-8. Event DX2-8 merely labels its inputs as all dealing with options in which a second man does not cross the boundary with the adversary. The two "label" events, DX2-7 and DX2-8, are the inputs to OR gate DX1-7. Finally, DX4-1 and DX4-2 are pseudo-events (equivalent to comments) pertaining to event DX3-5. They remind the analyst of two things that are concurrently relevant: that the second man can also be an adversary and that this additional adversary must be analyzed by the full tree, D-ACQUIRE. So, DX4-1 and DX4-2 are inputs to AND gate DX3-9.

"RELEASE" GENERIC LOGIC TREES

There are two generic logic trees titled RELEASE: one each for releasing SNM by stealth and force tactics. The primary events of each tree can be divided into two groups: (1) how the adversary accomplishes the release of SNM and (2) how the adversary remains undetected (when using stealth tactics) or overcomes any opposition that he encounters (when using any tactics), at least until the release has been initiated.

A RELEASE generic logic tree is to be used only when the adversary has reached the location where he can employ a release mechanism. If his scenario requires that he acquire SNM and bring it (or have it brought by someone else) to the location of the release mechanism, the analyst should use the appropriate ACQUIRE SNM tree, and also the necessary BOUNDARY, AREA, and BUILDING trees to follow the scenario to the point where the release mechanism itself can be employed.

A release of SNM might be caused in any of several ways, some of them involving several targets, or various environmental preconditions. Though a RELEASE logic tree is more complex than most generic trees, it only alludes to release mechanisms rather than analyzing them in detail.

One question to ask in a qualitative evaluation of the logic tree is, "Can the adversary initiate his chosen release mechanism and satisfy all its preconditions?" The adversary needs to be well informed about release mechanisms, the achievability of preconditions, and be suitably skilled and equipped. For the STEALTH-RELEASE tree a second question is, "Is it likely that the adversary can avoid or disable the detection elements without an alarm being generated?" For the FORCE-RELEASE tree, a second question is, "Is it likely that the adversary can overcome any opposition that he encounters?"

If a quantitative evaluation is needed, one question to ask is, "How much time will the adversary need to accomplish the tasks for release of SNM or to establish that the preconditions have been met?" This time is relevant for analysis only if it occurs during the attack. The other quantitative question is, "What is the probability that the adversary will be detected as he attempts to cause a release of SNM?"

STEALTH-RELEASE

Figure A-11 shows a simplified version of the generic logic tree, STEALTH-RELEASE. There are 14 primary events (S1-2, S1-4, S2-1, S2-2, S2-3, S2-5, S2-6, S2-7, S3-1, S3-2, S3-3, S3-4, S3-5, SX3-6). These can be divided into two groups. One group concerns the adversary's need to accomplish the release of SNM (S2-3, S2-5, S2-6, S2-7, S3-1, S3-2, S3-3, S3-4, S3-5). The other group concerns the adversary's need to remain undetected, at least until the release has been initiated (S1-2, S1-4, S2-1, S2-2, SX3-6).

The logic tree assumes that release of SNM can be accomplished in several ways. The released SNM can be propagated offsite by air (airborne release, see events S2-3, S2-4, S2-5, S2-6), or by other means (examples cited in the description of event S2-7 are release into groundwater or wastewater). The release can be accomplished by working on the SNM itself after acquiring it ("Direct involvement with SNM", see events S2-4, S2-6, S2-7) or by causing one or more system faults that will eventually result in an SNM release ("Indirect involvement with SNM," see events S2-3, S2-5, S2-7). The release can be accomplished by the use of explosives (see events S2-5, S2-6) or without explosives (see events S2-3, S2-4). Both cases might be appropriate for development under event S2-7. These several methods of causing a release of SNM should present different problems to the adversary.

The elements of the physical protection system that are the last defense against a release of SNM are not named in events S2-3, the development of S2-4 (i.e., S3-1, S3-2, S3-3, S3-4, S3-5, SX3-6), S2-5, S2-6, or S2-7. It is the analyst's job to supply these elements from the design which he is evaluating. However, events S2-3, S2-5, and S2-6 are developed events; they are further developed on the complete generic logic tree, STEALTH-RELEASE. That development is ignored in this discussion.

Figure A-11. STEALTH-RELEASE SNM Logic Tree

The maximum development has been retained in the abridged logic tree from the complete generic logic tree STEALTH-RELEASE only for event S2-4, "Airborne SNM release without explosives via direct involvement with SNM." The release is represented as a number of events all of which must occur for the adversary to be successful. First the adversary must at least breach the containment of the SNM whether or not he finds it necessary to take possession of the SNM (S3-1). Then the adversary must penetrate any barriers between the no-longer-contained SNM and the atmosphere (S3-2). For example, high-efficiency particulate air (HEPA) filters might be breached so that the ventilation system could be used as the release mechanism. But for this scenario to succeed, it is necessary that the SNM be in the proper form, for example, a fine powder, so that the ventilation system will in fact be able to pick up the SNM and inject it into the outside atmosphere (S3-3). For some release mechanisms that do not use explosives for SNM dispersal, it may be possible for a damage control operation to either prevent or limit the incipient release if it is discovered early and the release mechanism works slowly enough (S3-4). Even if an adversary succeeds in releasing SNM to the atmosphere, the release might not reach offsite unless meteorological conditions (e.g., wind velocity and direction) are favorable (S3-5).

Two kinds of elements detect an attempt to release SNM. One kind would be associated with release mechanisms in locations where the attempt could be detected before the release is achieved (S3-6, a basic event). Examples named in the event description detect use of doors that give access to a release mechanism, and the presence of SNM in the vicinity of a release mechanism where it would not be expected or permitted. The analyst must identify the possible release mechanisms so that he may assess how thoroughly the physical protection system provides for pre-release detection. One cannot be assured of distinguishing a release attempt from a theft attempt by which sensors are activated. Adequate assessment is necessary.

The second kind of element is personnel that can see or encounter the adversary attempting to achieve a release of SNM (S1-2, S1-4, S2-1, S2-2). Guards on patrol or stationed in observation towers are one example (S2-1, S2-2). These would be a trained part of the physical protection system. If they alone could not be positive measures for detection, they may reinforce the other kinds of detection elements to produce positive measures.

The two events that name guards as detection elements list two ways that an adversary might not be detected. He can avoid being seen by the guards (S2-1), or, if he is seen, he may be able to prevent the guards from sounding an alarm (S2-2). While the latter method of avoiding detection may be forceful rather than stealthy, it represents an action required of the adversary if he is to continue his attack by stealth, undetected, after he accidentally confronts a guard. The adversary may be able to hide until the patrol guards have passed and then use the period until the patrol is repeated to release SNM. It may be difficult for an adversary to know whether or not he is being seen from an observation tower (assuming that the SNM is being released from an outdoor location) or to prevent the sounding of an alarm if he knows that he has been seen.

Operations personnel may be nearby when the adversary acts to release SNM and see the actions (S1-4). Depending on the work schedule of a particular site, the adversary may be confident of avoiding accidental observation. Confrontation would be an unintended complication of an attack by stealth, and it may increase the chance of being observed by other operations personnel or guards.

Reinforcements for the security force (S1-2) would be called only after detection. If the time between notification of the security force and its arrival is long enough that the adversary cannot be intercepted before release of SNM is initiated, only a damage control team or system remains to mitigate or nullify the adversary's success. Thus, this event is important during release of SNM. This event may instead be meaningful with respect to detection during a prior step of the scenario such as crossing a boundary, traversing an area, entering a building, or acquiring SNM.

Having examined all primary events on the simplified logic tree, the logic by which they generate the end event is examined next. The adversary must initiate the release of SNM and he must avoid detection at least until this is accomplished. This is the fundamental logical statement made in the logic tree. All other detail merely elaborates on the possibilities. The fundamental logical statement is made by AND gate S-RELEASE. The input for initiating the release of SNM comes from event S1-3. All other inputs (S1-1, S1-2, S1-4) supply requirements for avoiding detection by personnel who may encounter the adversary where he is attempting to initiate the release.

Initiating release of SNM (S1-3) is generated by an OR gate whose inputs (S2-3, S2-4, S2-5, S2-6, S2-7) are the optional methods of performing a sabotage act on SNM. All of these options but one (S2-4) are developed events. The option of "Airborne SNM release without explosives, via direct involvement with SNM" is generated by an AND gate which repeats the fundamental logical statement of the logic tree. The inputs for initiating the release of SNM come from events S3-1, S3-2, S3-3, S3-4, and S3-5. The other input, SX3-6, is the requirement for avoiding detection by hardware systems before the release is initiated.

One other development appears on the tree. Event S1-1, "Avoid or confront guards -- alarm not sounded," states an option. The necessary logic is an OR gate, S1-1, with inputs S2-1 and S2-2. The same sort of option is implied for S1-2 and S1-4, both undeveloped events. Their developments would have the same logical form as the development of S1-1.

FORCE-RELEASE

Figure A-12 shows a simplified version of the generic logic tree, FORCE-RELEASE. There are 13 primary events (F1-2, F1-4, F2-1, F2-2, F2-3, F2-5, F2-6, F2-7, F3-1, F3-2, F3-3, F3-4, F3-5). These can be divided into two groups. One group concerns the adversary's need to initiate release of SNM (F2-3, F2-5, F2-6, F2-7, F3-1, F3-2, F3-3, F3-4, F3-5). The other group concerns the adversary's need to overcome any opposition that he encounters while initiating release of SNM (F1-2, F1-4, F2-1, F2-2).

Figure A-12. FORCE-RELEASE SNM Logic Tree

One event on STEALTH-RELEASE has no counterpart on FORCE-RELEASE. This exception is SX3-6, "Adversary defeats prerelease alarms -- door, SNM, etc." By definition, when using the force tactic the adversary expects to be detected, so the FORCE trees have no events that require the adversary to take action against the detection system.

APPENDIX B
Complete Generic Physical Protection Logic Trees

PENETRATOR
UNDETECTED
GROUP
PER

DEFEAT PROTECTED
BOUNDARY BY STEALTH
UNDETECTED BY PPS

S-BOUNDARY

AVOID OR CONFRONT
PATROL GUARDS
UNDETECTED

S1-30

AVOID OR CONFRONT
REINFORCEMENTS
UNDETECTED

G-30

AVOID OR CONFRONT
STATIONARY GUARDS
UNDETECTED -IN
TOWERS, ETC.

S-40

DEFEND BOUNDARY
AND AWAY FROM
LEVEL
METER

S-20

AVOID DETECTION BY
PATROL GUARDS

S2-30

DISABLE PATROL
GUARDS WITHOUT ALARM
SOUNDED

S2-40

AVOID DETECTION BY
STATIONARY GUARDS

S2-50

DISABLE STATIONARY
GUARDS WITHOUT ALARM
SOUNDED

S2-60

DEFEAT BOUNDARY
-UNDETECTED VIA
UNDERGROUND OR
UNDERWATER ROUTE

S3-80

TITLE	
STEALTH-BOUNDARY A	
DRAWING NUMBER	DATE
12.27.50	79/01/11

PENETRATE ENTRANCE
BOUNDARY AND
BARRIERS FACING
UNPROTECTED AREA

SS-40

PENETRATE VIA NORMAL
PERSONNEL ROUTE

SS-10

PENETRATE
HALLS, ROOF, VENTS,
ETC., OF PERSONNEL
ENTRANCE

SS-20

DEFEAT OR BYPASS
SENSORS

SX6-30

DEFEAT OR BYPASS
DETECTION SYSTEM OF
PERSONNEL ENTRANCE

SX5-50

DEFEAT COMMUNICATION
OF ALARM

SX6-40

DEFEAT OR BYPASS
ASSESSMENT OF ALARM

SX6-50

1

INEL
PER OR
TED

TITLE	
[REDACTED]	
STEALTH-BOUNDARY 8	
DRAWING NUMBER	DATE
12.27.50	79/01/11

DEFEND PROTECTED
BOUNDARY BY FORCE

F-BOUNDARY

AVOID OR
SUCCESSFULLY
CONFRONT PATROL
GUARDS

F1-30

AVOID OR
SUCCESSFULLY
CONFRONT
REINFORCEMENTS

F1-30

AVOID OR SUCCESS-
FULLY CONFRONT
STATIONARY GUARDS IN
TOWERS, ETC.

F1-40

AVOID PATROL GUARDS

F2-30

SUCCESSFULLY
CONFRONT PATROL
GUARDS

F2-40

AVOID STATIONARY
GUARDS

F2-50

SUCCESSFULLY
CONFRONT STATIONARY
GUARDS

F2-60

AVOID AREA P

F2-70

DEFEND BOUNDARY VIA
UNDERGROUND OR
UNDERWATER ROUTE

F3-80

LY
CHART

TITLE	
FORCE-BOUNDARY 1	
[REDACTED]	
DRAWING NUMBER	DATE
12.27.50	79/00/13

DEFER PERSONNEL
ENTRANCE - GATE,
PORTAL OR BUILDING

F3-20

BYPASS PERSONNEL
ENTRANCE - OVER OR
UNDER

F4-70

PENETRATE ENTRANCE
BOUNDARY AND
BARRIERS FRONTING
PROTECTED AREA

F5-80

BYPASS PERSONNEL
ENTRANCE

F5-90

AVOID OR
SUCCESSFULLY
CONFRONT GUARDS AT
PERSONNEL ENTRANCE

F5-110

GO VIA NORMAL
ANEL ROUTE

F6-100

PENETRATE WALLS,
ROOF, VENTS, ETC. OF
PERSONNEL ENTRANCE

F6-110

AVOID GUARDS AT
PERSONNEL ENTRANCE

F6-150

SUCCESSFULLY
CONFRONT GUARDS AT
PERSONNEL ENTRANCE

F6-160

DEFEAT BOUNDARY BY
DECEIT
-AT ENTRANCE

D-BOUNDARY

SEE NOTES 1, 2 AND 3

ADVERSARY DEFEATS
AUTHORIZATION CHECK,
IF ANY

DX1-10

ADVERSARY HAS NO
IDENTITY
CREDENTIALS- DEFEATS
OR AVOIDS CHECK

DX2-80

ADVERSARY IS
CORRECTLY AUTHORIZED
FOR ACCESS THROUGH
BOUNDARY

DX2-70

ADVERSARY HAS
COUNTERFEIT AUTHORI-
ZATION TO BE IN
AREA- PASSES CHECK

DX2-80

ADVERSARY IS NOT
AUTHORIZED ACCESS
THROUGH BOUNDARY- IS
ACCEPTED

DX2-90

2 MAN RULE IS
ENFORCED- 2ND PER-
SON ENTERS WITH
ADVERSARY

DX2-100

ADVERSARY DECEIVES
2ND PERSON

DX3-10

ADVERSARY HAS
COLLABORATION OF
PERSON-
INSIDER

DX3-20

NOTE 1. EXAMPLES OF ADVERSARY OR COLLABORATOR

INSIDER

EMPLOYEE OF

CONTRACTOR

SITE

TYPE OF EMPLOYEE

ADMINISTRATIVE

GUARD

GATE

PATROL

STATIONARY...E.G., IN TOWER

HEALTH PHYSICS

MAINTENANCE

MANAGER/SUPERVISOR

OPERATIONS

2ND PERSON OF TWO-MAN TEAM

OUTSIDER DISGUISED AS ANY OF
THE ABOVE INSIDERS

NOTE 2. CONDITIONS OF COLLABORATION

COERCED

WILLING

NOTE 3. EXAMPLES OF AREAS

PROTECTED

LIMITED

VITAL

MATERIAL ACCESS

TITLE DECEIT-BOUNDARY, A	
	DRAWING NUMBER 08.49.53	DATE 05/22/79

CTORS, IF

20

METAL, SNM DETECTORS

OPENLY REMOVE SNM
WITH SOME
AUTHORIZATION

DX2-140

GATE GUARD ACCEPTS
AUTHORIZATION FOR
MATERIAL

DX3-90

2 MAN RULE IF USED
FAILS TO PREVENT
REMOVAL OF SNM

DX3-100

AUTHORIZATION
DECEIVES GATE GUARD

DX4-120

GATE GUARD
COLLABORATES WITH
ADVERSARY

DX4-130

2 MAN RULE NOT
ENFORCED- NO 2ND
PERSON WITH
ADVERSARY

DX4-140

EXPLOIT OR CAUSE
ENFORCEMENT SYSTEM
FAILURE

DX5-60

ENFORCEMENT PER-
SONNEL COLLABORATE-
ALLOW ADVERSARY TO
REMOVE SNM, ALONE

DX5-70

ENFORCEMENT
PERSONNEL DECEIVED
BY ADVERSARY

DX5-80

ADVERSARY DECE
2ND PERSON

DX5-90

TITLE DECEIT-BOUNDARY, 8	
	DRAWING NUMBER 08.49.53	DATE 05/22/79

TRAVERSE AREA
UNDETECTED

S1-10

DEFEAT BARRIERS, IF
ANY,
UNDETECTED

S1-20

DEFEAT PASSIVE
BARRIERS, IF ANY,
UNDETECTED

S2-10

DEFEAT ACTIVE
BARRIERS, IF ANY,
UNDETECTED

S2-20

AVOID OR CONFRONT
PATROL GUARDS
UNDETECTED

S1-30

AVOID PATROL GUARDS

S2-30

SUCCESSFULLY
CONFRONT PATROL
GUARDS WITHOUT ALARM
SOUNDED

S2-40

AVOID OR CONFRONT
REINFORCEMENTS
UNDETECTED

S1-40

AVOID S
GU

S

DEFEAT PROTECTED
AREA BY STEALTH
UNDETECTED

S-AREA

AVOID OR CONFRONT
STATIONARY GUARDS
UNDETECTED

S1-50

AVOID STATIONARY
GUARDS

S2-50

SUCCESSFULLY
CONFRONT STATIONARY
GUARDS WITHOUT ALARM
SOUNDED

S2-60

AVOID OR CONFRONT
AREA PERSONNEL
UNDETECTED

S1-80

AVOID DETECTION BY
AREA PERSONNEL

SK2-70

PREVENT AREA
PERSONNEL FROM
SOUNDING AN ALARM

SK2-80

DEFEAT OR BYPASS
SENSOR

SK2-90

ED OR CONFRONT
AREA PERSONNEL
UNDETECTED

S1-80

DEFEAT OR BYPASS
DETECTION SYSTEM

SX1-70

PREVENT AREA
PERSONNEL FROM
SOUNDING AN ALARM

SX2-80

DEFEAT OR BYPASS
SENSOR

SX2-90

DEFEAT COMMUNICATION
OF ALARM

SX2-100

DEFEAT OR BYPASS
ASSESSMENT OF ALARM

SX2-110

TITLE

STEALTH-AREA

DRAWING NUMBER

08.17.52

DATE

09/05/79

NOT PROTECTED
BY FORCE

F-AREA

AVOID OR
SUCCESSFULLY
CONFRONT PATROL
GUARDS

F1-30

SUCCESSFULLY
CONFRONT PATROL
GUARDS

F2-40

AVOID OR
SUCCESSFULLY
CONFRONT
REINFORCEMENTS

F1-40

AVOID STATIONARY
GUARDS

F2-50

AVOID OR SUCCESS-
FULLY CONFRONT
STATIONARY GUARDS
- IN TOWERS, ETC.

F1-50

SUCCESSFULLY
CONFRONT STATIONARY
GUARDS

F2-60

AVOID OR
SUCCESSFULLY
CONFRONT AREA
PERSONNEL

F1-60

DEFERT AREA BY
DECEIT

D-AREA

SEE NOTES 1,2 AND 3

DEFERTS
IDENTIFICATION
IF ANY

-30

ADVERSARY DEFERTS
AUTHORIZATION CHECK,
IF ANY

DX1-40

ADVERSARY HAS
NO IDENTITY
CREDENTIALS- DEFERTS
OR AVOIDS CHECK

-50

ADVERSARY HAS NO
IDENTITY
CREDENTIALS- DEFERTS
OR AVOIDS CHECK

DX2-60

ADVERSARY IS
CORRECTLY AUTHORIZED
TO BE IN AREA

DX2-70

ADVERSARY HAS
COUNTERFEIT AUTHOR-
IZATION TO BE IN
AREA- PHYSICS CHECK

DX2-80

ADVERSARY IS NOT
AUTHORIZED TO BE IN
AREA- IS ACCEPTED

DX2-90

2 MS
ENFORCE
TRAVEL
NO

10

ADVERSARY DECEIVES
2ND PERSON

DX3-10

ADVER
COLLABOR
PE
11

11

NOTE

NOTE

NOTE

NOTE 1. EXAMPLES OF ADVISORY OR COLLABORATION

INSIDER

EMPLOYEE OF
CONTRACTOR
SITE

TYPE OF EMPLOYEE:
ADMINISTRATIVE
GUARD

GATE

PERMIT

STATIONARY...E.G., IN TOWER

HEALTH SERVICES

MAINTENANCE

MANAGEMENT SUPERVISOR

OPERATIONS

2ND PERSON OF TWO-MAN TEAM

OUTSIDER DISGUISED AS ANY OF
THE ABOVE INSIDERS

NOTE 2. CONDITIONS OF COLLABORATION

COERCED

WILLING

NOTE 3. EXAMPLES OF AREAS

PROTECTED

LIMITED

VITAL

MATERIAL ACCESS

	TITLE DECEIT-AREA	
	ORIGIN NUMBER 11.36.48	DATE 79/03/19

PENETRATE BUILDING
BOUNDARY UNDETECTED

S1-10

PENETRATE NORMAL
ENTRANCE, UNDETECTED-
PERSONNEL, EQUIPMENT,
SAFETY EXIT, ETC.

S2-20

PENETRATE
SAFETY
EXIT

PENETRATE OUTSIDE
DOOR OR BARRIER
UNDETECTED

S3-50

PENETRATE AREA AND
BARRIERS BETWEEN
DOORS UNDETECTED

S3-60

DEFEAT OTHER
ENTRANCE BARRIERS
UNDETECTED

S3-70

PENETRATE INSIDE
DOOR OR BARRIER
UNDETECTED

S3-80

DEFEAT OR BYPASS
DETECTION SYSTEM
BUILDING ENTRANCE

SK3-90

DEFEAT OR BYPASS
ASSESSMENT OF ALARM

SK4-80

DEFEAT OR BYPASS
BUILDING ENTRANCE
SENSORS

SK4-70

DEFEAT COMMUNICATION
OF ALARM

SK4-90

DEFEAT OR BYPASS
DOOR ALARM IF
PRESENT

SK5-10

DEFEAT OR BYPASS
SPACE ALARM IF
PRESENT

SK5-20

DEFEAT OR BYPASS SWM
ALARM IF PRESENT

SK5-30

DEF
BOUND

PENETRATE PERSONNEL
SAFETY ESCAPE
UNDETECTED

S2-30

DEVELOP WHEN
APPLICABLE
MAY BE SIMILAR TO
S2-20

DEFLECT OR BYPASS
ECTION SYSTEM OF
ILDING ENTRANCE

SK3-90

DEFLECT COMMUNICATION
OF ALARM

SK4-80

DEFLECT OR BYPASS
ASSESSMENT OF ALARM

SK4-90

AVOID DETECTION BY
ENTRANCE GUARDS

SK4-100

AVOID OR DEFLECT
GUARD UNDETECTED AT
BUILDING ENTRANCE

S3-100

DISABLE ENTRANCE
GUARD WITHOUT ALARM
SOUNDED

SK4-110

PENETRATE SERVICE
INLET UNDETECTED

S3-110

DEFLECT SERVICE
BARRIERS UNDE

S3-120

DEFLECT OR BYPASS
METAL AND EXPLOSIVE
DETECTOR ALARMS IF
PRESENT

SK5-40

DEFEAT BUILDING
BOUNDARY BY STEALTH
UNDETECTED

S-BLDG

AVOID OR CONFRONT
PATROL GUARDS
UNDETECTED

S1-20

AVOID DETECTION BY
REINFORCEMENTS

S1-30

AVOID OR CONFRONT
STATIONARY GUARDS
UNDETECTED

S1-40

PENETRATE SERVICE IN-
LETS UNDETECT.-VENTS
WINDOWS, UTILITY TUN-
NELS, SEWERS, ETC.

S2-40

AVOID PATROL GUARDS

S2-50

SUCCESSFULLY
CONFRONT PATROL
GUARDS WITHOUT ALARM
SOUNDED

S2-60

AVOID STATIONARY
GUARDS

S2-70

SUCCESS
CONFRONT ST
GUARDS WITH
SOUND

S2-80

DEFEAT SERVICE INLET
BARRIERS UNDETECTED

S3-120

DEFEAT SERVICE INLET
ALARMS,
COMMUNICATION, OR
ASSESSMENT

SK3-130

DEFEAT SERVICE INLET
SNM MONITORS,
COMMUNICATION, OR
ASSESSMENT

SK3-140

TITLE: [REDACTED]	
STEALTH-BUILDING	
DRAWING NUMBER	DATE
13.10.10	79/01/12

DEFEAT BUILDING
BOUNDARY BY FORCE

F-BLD3

AVOID OR
SUCCESSFULLY
CONFRONT PATROL
GUARDS

F1-20

PENETRATE PERSONNEL
SAFETY ESCAPE

F2-30

DEVELOP WHEN
APPLICABLE
MAY BE SIMILAR TO
F2-20

PENETRATE INNER DOOR
OR BARRIER

F3-80

SUCCESSFULLY
CONFRONT ENTRANCE
GUARDS IF PRESENT

F3-100

DEFEAT SERVICE
INLETS- VENTS,
WINDOWS, UTILITY
TUNNELS, SENSORS, ETC

F2-40

PENETRATE SERVICE
INLET

F3-110

DEFEAT SERVICE INLET
BARRIERS

F3-120

AVOID PATROL GUARDS

F2-50

AT BUILDING
WARY BY FORCE

F-BLD3

SERVICE INLET
BARRIERS

F2-120

ACQUIRE SNM FROM
LOADING OR UNLOADING BY
FORCE

F-ACQUIRE

AVOID OR
SUCCESSFULLY
CONFRONT PATROL
GUARDS

F1-20

AVOID OR
SUCCESSFULLY
CONFRONT
REINFORCEMENTS

F1-30

AVOID OR
SUCCESSFULLY
CONFRONT AREA
PERSONNEL

F1-50

TO PATROL GUARDS

F2-60

SUCCESSFULLY
CONFRONT PATROL
GUARDS

F2-70

ACQUIRE SNM FROM
BUILDING OR VAULT BY
DECEIT

D-ACQUIRE

SEE NOTES 1, 2 AND 3

DEFEAT OR IGNORE
MATERIAL ACCOUNTING
SYSTEM

DX3-40

ADVERSARY NOT
DEFEATED BY AREA
PERSONNEL, IF ANY

DI-50

2 MW
FA
RE
PE

ADVERSARY IGNORES
MATERIAL ACCOUNTING
SYSTEM

DX2-100

SPOOF MATERIAL
ACCOUNTING SYSTEM

DX2-110

ADVERSARY HAS
COLLABORATION OF SNM
DETECTION SYSTEM
PERSONNEL

DX3-30

MATERIAL ACCOUNTING
SYSTEM TOO SLOW

DX3-40

MATERIAL ACCOUNTING
SYSTEM FAILS

DX3-50

SPOOF MATERIAL
ACCOUNTING SYSTEM
WITH PAPERWORK

DX3-60

SPOOF MATERIAL
ACCOUNTING SYSTEM
WITH SUBSTITUTION OF
MATERIAL

DX3-70

NOTE 1. EXAMPLES OF ADVERSARY OR COL

INSIDER

EMPLOYEE OF
CONTRACTOR
SITE
TYPE OF EMPLOYEE
ADMINISTRATIVE
GUARD
GATE
PATROL
STATIONARY...E.G
HEALTH PHYSICS
MAINTENANCE
MANAGER/SUPERVISOR
OPERATIONS
2ND PERSON OF TWO-MAN TEAM
OUTSIDER DISGUISED AS ANY OF
THE ABOVE INSIDERS

NOTE 2. CONDITIONS OF COLLABORATION

COERCED
WILLING

NOTE 3. EXAMPLES OF AREAS

PROTECTED
LIMITED
VITAL
MATERIAL ACCESS

	TITLE
	DECEIT-1
	DRAWING NUMBER
	11.23.18

NOTE 1. EXAMPLES OF ADVERSARY OR COLLABORATOR

INSIDER

EMPLOYEE OF
CONTRACTOR
SITE

TYPE OF EMPLOYEE
ADMINISTRATIVE
GUARD

GATE

PATROL

STATIONARY...E.G., IN TOWER

HEALTH PHYSICS

MAINTENANCE

MANAGER/SUPERVISOR

OPERATIONS

2ND PERSON OF TWO-MAN TEAM

OUTSIDER DISGUISED AS ANY OF
THE ABOVE INSIDERS

NOTE 2. CONDITIONS OF COLLABORATION

COERCED

WILLING

NOTE 3. EXAMPLES OF AREAS

PROTECTED

LIMITED

VITAL

MATERIAL ACCESS

TITLE DECEIT-ACQUIRE SNMA	
	DRAWING NUMBER 11.23.18	DATE 10/09/79

TITLE	
	DECEIT-ACQUIRE SNM 8	
	DRAWING NUMBER	DATE
	11.23.18	10/09/79

APPENDIX C
Alternate Version of DECEIT-BOUNDARY Logic Tree

ALTERNATE VERSION OF DECEIT-BOUNDARY LOGIC TREE

Experience with the DECEIT-BOUNDARY generic physical protection logic tree presented in Appendix B has repeatedly led to this criticism: there is something confusing about how the identity check and authorization check subtrees should be interpreted and applied to a real physical protection system. Anticipating that some readers will share this reaction, an alternate version of DECEIT-BOUNDARY is presented in this Appendix. If reaction to this alternate version indicates that it has solved or reduced the problem, it or an improved version will become the single standard DECEIT-BOUNDARY logic tree. Meanwhile, this alternate version of DECEIT-BOUNDARY is offered for trial and comment.

DECEIT-BOUNDARY has to do with access control, of which identity checks and authorization checks are vital elements. In the alternate logic tree another element is added: a person must be enrolled in the access control system to have his authorization for access established. Event DX1-10 requires that the "Adversary Defeats or Bypasses Enrollment Procedure for Authorization." This event probably takes place long before the scenario when the adversary attempts to gain access through the boundary in question.

As a result of enrollment for access authorization, a record is created to document that person X is authorized to enter area A, perhaps under certain conditions. The access authorization is a fact, the result of an administrative action, and exists apart from any credential which, in the possession of an employee, is meant to certify or refer to the authorization. In the alternate DECEIT-BOUNDARY, all references to "credentials" have been eliminated as possibly misleading. By definition, a credential is something that gives title to credit or confidence; it is presumed to certify authority for access. But devices commonly called credentials (badges, key cards, etc.) can be forged or stolen and do not warrant naive acceptance. The generic physical protection problem is to check a claim of authorization under the rules of the system. The mechanism for making the claim may or may not be vulnerable to misuse by the adversary. The rules of the system may or may not be likely to expose misuse.

Event DX1-20 requires that the "Adversary Defeats Access Authorization Check." The subtree gives three alternatives: (1) DX2-10, "Correct Access Authorization Claim Confirmed," (2) DX2-20, "Collaborator Accepts Incorrect Access Authorization Claim," or (3) DX2-30, "System Fails to Reject Incorrect Access Authorization Claim."

An identity check is a screening technique to assure that the individual who seeks to have the authorization of X checked and access granted is indeed X. Unless the identity is correctly established by a truly unique characteristic of the individual himself, there is a chance that an adversary can use the access authorization

of someone else. A claim of an identity is made and must be checked so it can be confirmed or rejected.

Event DX1-30 requires that the "Adversary Defeats Identity Check." The subtree gives three alternatives as in the case of the authorization check: (1) DX2-40, "Correct Identity Claim Confirmed," (2) DX2-50, "Collaborator Accepts Incorrect Identity Claim," or (3) DX2-60, "System Fails to Reject Incorrect Identity Claim."

Other than the above major changes from the DECEIT-BOUNDARY logic tree in Appendix B, there are a few changes in event descriptions intended to improve understandability and the elimination of a few events that have been found not to be related to positive measures for physical protection (i.e., the subtree "Adversary Not Detected Crossing Boundary by Area Personnel," since area personnel, excluding guards, normally have no role in access control, and would contribute only accidentally to physical protection).

DECEIT-BOUNDARY
ALTERNATE A

DECEIT-BOUNDARY
ALTERNATE R