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EASI Program Improvements for HP-67 and TI-59 Calculators

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ABSTRACT

EASI (Estimate of Adversary Sequence Interruption) is an effective, simple method which has been developed for use in evaluating physical security systems. The usefulness of the method is enhanced by the fact that it can be implemented on a programmable pocket calculator. New EASI programs for the Hewlett-Packard HP-67 and the Texas Instruments TI-59 calculators are provided. These new programs store the input data for subsequent recall or change. Thus, to perform sensitivity analyses, the user may selectively change different parameters stored in the calculator; it is not necessary to reenter the original input data as in previously developed EASI programs. The new programs eliminate not only the inconvenience of repeated data reentry, but also the potential source of error inherent in data entry.

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I. INTRODUCTION

A simple, easy-to-use method called Estimate of Adversary Sequence Interruption (EASI) has been developed to evaluate physical security system performance under specified conditions of threat and system operation.[1-3] The method consists of a probabilistic analysis of the interactions of basic security functions such as detection, assessment, communications, delay, and response time to obtain an estimate of the probability of interrupting an adversary sequence. In addition to its simplicity, EASI can be programmed on a hand-held programmable calculator. Both of these features combine to make EASI a useful method for quick, first-order evaluations of physical security systems.

The purpose of this report is to provide new EASI programs for the Hewlett-Packard HP-67 and the Texas Instruments TI-59 calculators. These new programs store the input data for subsequent recall or change. Thus, to perform sensitivity analyses, the user may selectively change different parameters stored in the calculator--it is not necessary to reenter the original input data as in previously developed EASI programs. The new programs not only eliminate an inconvenience but the potential source of error in repeated reentry of data.

To provide this capability on the HP-67, it was necessary to overcome the inherent storage limitations by using a technique for "packing" data into the storage registers. With this technique, the HP-67 can be used to calculate the probability of interruption for an Adversary Action Sequence (AAS) with up to 22 tasks and 22 sensors. Efforts to apply similar data "packing" techniques to the Texas Instruments SR-52 calculator (no longer produced) were unsuccessful. However, the new TI-59 can be programmed to handle up to 25 tasks and 25 sensors without resorting to "data packing." In addition to the improved EASI program, an additional TI-59 program is provided in this report which will allow TI-59 users to follow the SR-52 example instructions given in the EASI user's guide.[2]

II. DISCUSSION

The following discussion which is included for clarity and completeness summarizes the description of the EASI methodology contained in References 1 and 2. Although the reader would not be required to refer to Reference 1, it would be advantageous for the user to have access to the EASI user's guide.[2]

The basis for the EASI method is that, for resolute theft or sabotage attempts to be averted at nuclear facilities, the response force* must be notified of the attempt while there is still sufficient time remaining in the AAS for the force to respond and interrupt the sequence. The response force is assumed to be adequate at least to delay adversary progress until additional forces arrive to neutralize the adversary. The actual force composition required is a function of the threat and must be determined by other means.

The EASI evaluation method is a probabilistic approach which analytically evaluates basic functions of the physical security system (detection, assessment, communications, and delay) with respect to response time and provides an estimate of the probability of adversary sequence interruption. A mathematical derivation of the EASI method is contained in Appendix A.

Data Collection

The steps for applying the EASI method are

1. Obtain or develop a site and facility layout, including design and operational characteristics, in sufficient detail to identify adversary targets as a function of hypothesized adversary goals, motivations, and attributes.
2. Generate adversary action sequences relevant to the identified targets.

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*Although the term response force is used, other alternatives to force may be substituted provided they are adequate to delay adversary progress until the adversary can be neutralized.

3. Define the physical paths corresponding to the selected action sequence and choose a specific path, or set of paths, for analysis.
4. Determine locations of detectors and delay mechanisms along the selected path.
5. Obtain data for the probabilities of detection for all detectors and the probability of communication success.
6. Obtain the means and standard deviations of the time required to perform each of the adversary tasks.
7. Obtain the mean and standard deviation of the security force response time.
8. Use the input data applicable to the selected adversary path to perform the necessary calculations to estimate the probability of interruption.
9. Analyze other possible paths using the same technique in order to determine if any paths produce unacceptable results.
10. Change input parameters for the paths found in Step 9 (e.g., security force response time, communications probability, detection probability, etc.) one at a time to determine the impact of such changes on the overall probability of interrupting the adversary sequence.

One of the penalties of a simple evaluation method is that the user has the responsibility to assure that the input data properly reflects conditions of the actual security system. For instance, the probability of detection should represent an estimate applicable to the particular means of detection being considered, within the environment, facility operations, and threat expected.

III. TI-59 OPERATING PROCEDURES

The TI-59 programmable calculator is shown in Figure 1. Most of the keys on the TI-59 are double labeled--a label on the key itself and one just above it. These keys have two functions: the first function is denoted by the label on the key and is activated simply by depressing the key; the second function is the label above the key and is activated by depressing the [2nd] button and then the function key. For example, to activate the [A'] function, depress the [2nd] button followed by the [A] button.

The operating procedures are divided into four basic functions: programming the calculator, data entry, program execution, and data changes. These functions are discussed in the following paragraphs.

Programming the Calculator

The TI-59 calculator can be programmed by either of two methods: (1) the program steps listed in Appendix B can be manually entered while the calculator is in the learn mode (press the [LRN] key) or (2) the contents of a prerecorded magnetic card can be read into the calculator.

To read the program from a magnetic card, the following procedures apply:

1. Turn power on (located at the top, left side of the TI-59).
2. Read side 1 of the selected magnetic card by performing the following sequence of key manipulations: [9], [2nd], [Op], and [1] [7]. These keys are used to repartition the data memory. Then press [1] or [0] and insert the card in the lower slot located on the right-hand side of the calculator. Do not restrict or hold the card after it is caught by the drive mechanism. The display will remain blank until the calculator has completed reading side 1.
3. After the drive motor stops, remove the card from the left side of the calculator.

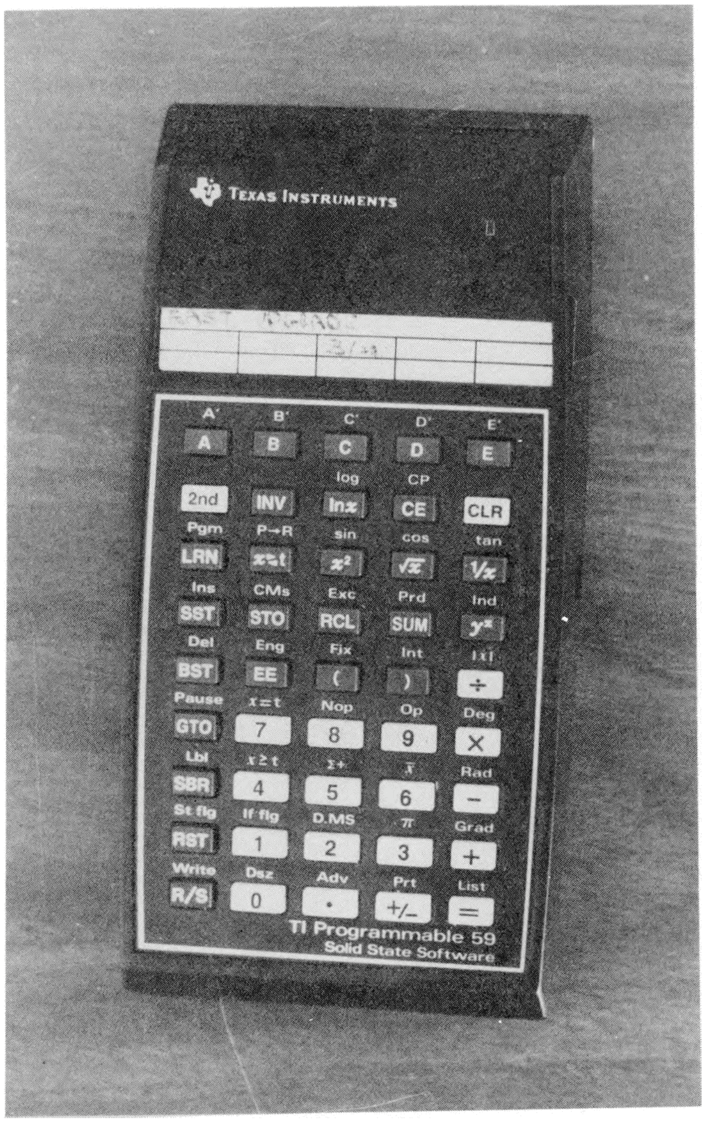


Figure 1. The TI-59 Programmable Calculator

If the display flashes immediately after Step 2 has been completed, press [CE] then [1] and reinsert the card. If difficulties still persist, refer to the "Maintenance and Service Information" contained in the owner's manual. The program is now loaded into program memory and will remain there until the calculator is either turned off, another card is read, or new instructions are keyed using the learn mode. The calculator is now ready for an example problem.

The following example for the TI-59 (Example 1 in Reference 2) is presented both to demonstrate the operating procedures and to verify to the user that the procedures have been properly interpreted. In this example, the adversary is a saboteur without authorization to enter the facility. The saboteur could try to gain entry by using false credentials (deceit mode) for which there is a probability that at the entrance the credential would be detected as being false. However, for this example it is assumed that the saboteur seeks to gain entry surreptitiously.

The path chosen for analysis is shown in Figure 2 and consists of the following sequence of events:

1. The adversary penetrates the boundary fence, t_1*, crosses the area between the fence and the main building, t_2 and t_3, and reaches the locked exterior door.
2. While outside, the adversary is subject to surveillance by closed-circuit television (CCTV), (Sensor 1).
3. After penetrating the exterior door, t_4, (Sensor 2), the adversary continues along a corridor to a second locked door, t_5.
4. The adversary penetrates this locked door, t_6, (Sensor 3), and enters a room which contains the vital component, t_7.

The adversary time-sequence path (in minutes) for the path indicated in Figure 2 is shown on page 17.

*t_i represents Task i, where i = 1,2,...

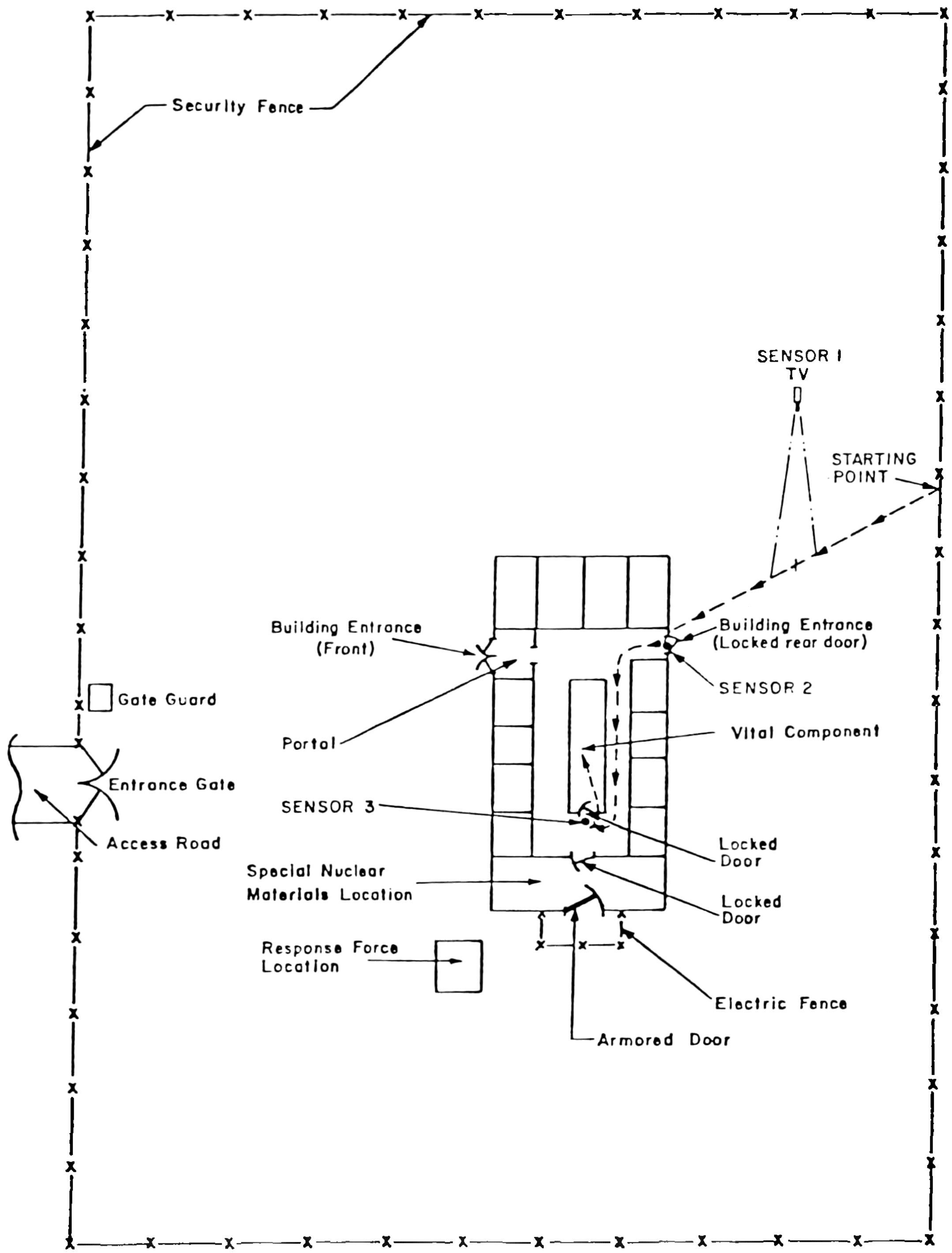
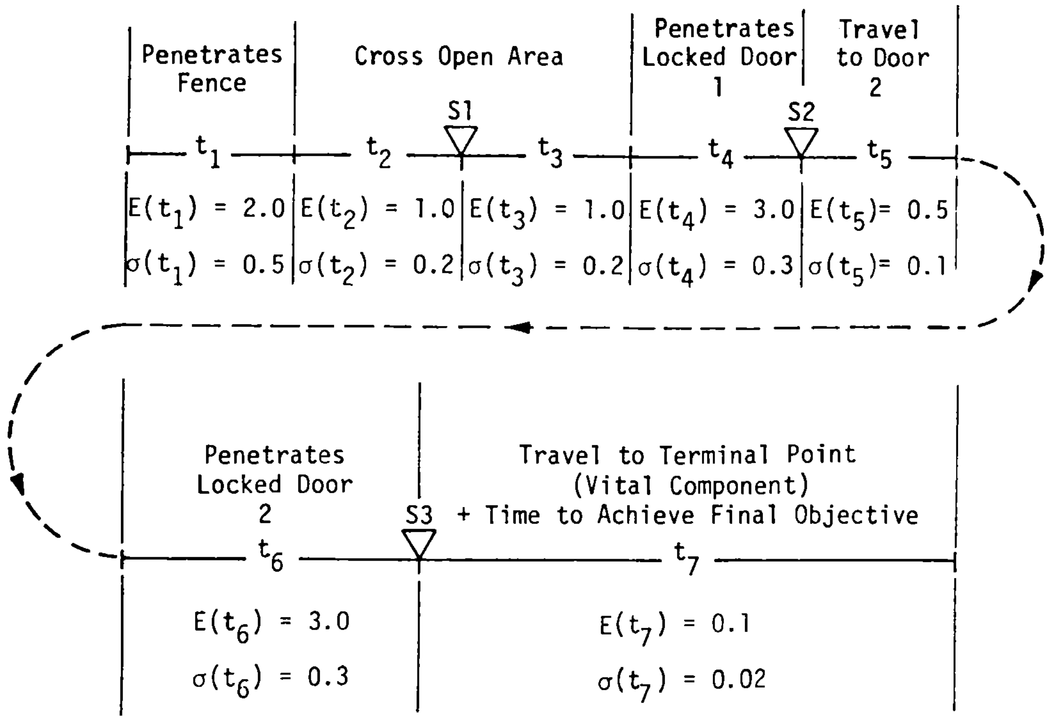


Figure 2. Adversary Path Used for TI-59 Example



NOTES:

1. Adversary task completion times must be divided at sensor locations, e.g., the time to cross the open area, $t_2 + t_3$, is arbitrarily divided in half in this example under the assumption that the CCTV coverage will detect movement close to the middle of the open area.
2. The detection probabilities P(d) for the three sensors are S1 = 0.3, S2 = 0.97, S3 = 0.97.
3. The communication probability P(C) is 0.9.
4. The response time of the security force is $E(t_r) = 4.0$ minutes with a $\sigma(t_r) = 0.16$ minute.

Data Entry

Data entry consists of initializing the program, entering the response data, and entering the adversary task data. The program must be initialized for each new problem in order to clear any previous data from the storage registers. To initialize, press [2nd] [E'] and wait until a zero is displayed.

The response force data which correspond to the evaluation conditions of interest are entered as follows:

Step	Procedure	Press	Display
1	Enter probability of communication, P(C)	0.9, 2^{nd}, A'	0.9
2	Enter expected response time $E(t_r)$	4, 2^{nd}, B'	4.
3	Enter standard deviation of response time, $\sigma(t_r)$	0.16, 2^{nd}, C'	0.0256

Note that with the exception of the standard deviation of the response time, each entered value is indicated in the display. For the standard deviation of the response time, the display indicates the variance of the response time or $\sigma^2(t_r)$.

The adversary tasks are numbered in chronological order and the task data are entered as follows:

Step	Procedure	Press	Display
4	Enter total number of adversary tasks (up to maximum of 25)*	7, 2^{nd}, D'	1. (prompting for 1st task data)
5	Enter probability of detection for Task 1, $P(d_1)$ (if no sensor at the start of that task, enter 0)**	0, A	0.
6	Enter expected time for Task 1, $E(t_1)$	2, B	2.
7	Enter standard deviation for Task 1, $\sigma(t_1)$	0.5, C	0.5 momentarily, then 2. (Next Task No.)
8	Enter probability of detection for Task 2, $p(d_2)$	0, A	0.
9	Enter expected time for Task 2, $E(t_2)$	1, B	1.
10	Enter standard deviation for Task 2, $\sigma(t_2)$	0.2, C	0.2 momentarily, then 3. (Next Task No.)

*The maximum number of tasks for which data can be stored is 25. If a number exceeding 25 is entered, a flashing "25" is displayed to indicate the error. Pressing the [CE] key will stop the flashing. The user must then redefine the adversary tasks to reduce the total number to 25 or less.

**All sensors are assumed to be located at the beginning of each task. If a sensor logically operates as a task is completed (i.e., opening a door), the sensor is assumed to operate at the start of the next task. If there is no sensor, enter zero.

Step	Procedure	Press	Display
11	Enter probability of detection for Task 3, $P(d_3)$ for Sensor 1	0.3, A	0.3
12	Enter expected time for Task 3, $E(t_3)$	1, B	1.
13	Enter standard deviation for Task 3, $\sigma(t_3)$	0.2, C	0.2 momentarily, then 4. (Next Task No.)
14	Enter probability of detection for Task 4, $P(d_4)$	0, A	0.
15	Enter expected time for Task 4, $E(t_4)$	3, B	3.
16	Enter standard deviation for Task 4, $\sigma(t_4)$	0.3, C	0.3 momentarily, then 5. (Next Task No.)
17	Enter probability of detection for Task 5, $P(d_5)$ for Sensor 2	0.97, A	0.97
18	Enter expected time for Task 5, $E(t_5)$	0.5, B	0.5
19	Enter standard deviation for Task 5, $\sigma(t_5)$	0.1, C	0.1 momentarily, then 6. (Next Task No.)
20	Enter probability of detection for Task 6, $P(d_6)$	0, A	0.
21	Enter expected time for Task 6, $E(t_6)$	3, B	3.
22	Enter standard deviation for Task 6, $\sigma(t_6)$	0.3, C	0.3 momentarily, then 7. (Next Task No.)
23	Enter probability of detection for Task 7, $P(d_7)$ for Sensor 3	0.97, A	0.97
24	Enter expected time for Task 7, $E(t_7)$	0.1, B	0.1
25	Enter standard deviation for Task 7, $\sigma(t_7)$	0.02, C	0.02 momentarily, then 7. (Repeating last Task No.)*

Program Execution

The program execution phase consists of either calculating the probability of interruption P(I) based on the time the adversary will

*After data for the last task have been entered, the last task number will again be displayed.

reach the designated terminal points or calculating P(I) for intermediate points (subcalculations). To calculate the probability of interruption to the terminal point, execute the step described below.

Step	Procedure	Press	Display	
26	Execute for P(I)	E	1st,	1.2131223-18*
			then,	.1120440888
			finally	.3517906773

Interruption probabilities for points along an adversary path, but prior to the designated terminal point, can be readily determined while entering the task data. Simply input the data for each task up to the point of interest, then enter the time required for the security force to respond to that location and press the [E] button. After the calculation is complete, enter the next task number into [D] and resume data entry. Note that the response time data may have to be changed at each point of interest in order to correctly reflect the amount of time required for the security force to arrive at that particular point on the path.

Data Changes

Changes to the data are required whenever input errors are made or whenever system sensitivity studies are performed. If a wrong number is entered into the display, press [CE], reenter the correct number, and continue the data entry procedures. However, if the user-defined keys have been pressed, one or more of the following procedures should be followed:

1. If the value entered for P(C), $E(t_r)$, or $\sigma(t_r)$ is in error, reenter the correct value using the appropriate user-defined key at any time prior to program execution.

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*To take advantage of programming simplicity, the actual calculation of the probability of interruption begins with the last adversary task and progresses in reverse chronological order. At each sensor location, the calculator pauses briefly to display the cumulative results from that point to the terminal point. Pressing [R/S] at this point will fix the display. To resume calculating, press [R/S] again. These intermediate results can be interpreted as the probability of interruption of that adversary action sequence if there were no other sensors located earlier (chronologically) along the path. Therefore, the changes in probability indicated in these intermediate results provide a measure of value of each sensor along the path.

2. If the total number of tasks is in error and no task data have been entered, reenter the correct number and press [2nd] [D']. However, if task data have been entered, reenter the correct number, press [2nd] [D'], and reenter all of the task data.
3. If there is an error in either $P(d_i)$, $E(t_i)$, or $\sigma(t_i)$ of some task and the data entry for that task is not yet complete, reenter the correct value and press the appropriate user-defined key. However, if the data entry for that task is complete, enter the number of the task requiring a data correction and press [D] to index the appropriate storage registers to accept the correct data. Enter the correct value using the appropriate user-defined key. Then enter the task number which will return you to the point at which the input procedure was interrupted, press [D], and resume the data input procedure.

The following example illustrates how to vary a parameter in order to determine the effect of such a change on the probability of interruption. If the detection probability, $P(d_3)$, associated with Sensor 1 were improved from 0.3 to 0.8, the following procedures would be used to make this change:

Step	Procedure	Press	Display
1	Enter the number of the task in which changes are to be made	3, D	3.
2	Enter the new value for $P(d_3)$	0.8, A	0.8
3	Execute for P(I)	E	.7513683248*

The other remaining task parameters, E(t) and $\sigma(t)$, could also have been changed at this time since all three storage registers for Task 3 were indexed to accept new data when [D] was pressed. Changes may be made at any time prior to a program execution.

To display data currently stored for any task, first enter the task number and press [D]. After the task number has been displayed,

---

*Final result.

press [R/S] to display the stored value for P(d). To display the stored value for E(t), press [R/S] again. Press [R/S] a third time to display the σ(t) value. Should the [R/S] key inadvertently be pressed a fourth time, a flashing zero will be displayed. Pressing the [CE] key will correct the error and allow continuation of the procedure.

To determine sensitivities to changes in response time (with Sensor 1 restored to its original detection probability), the procedure is as follows:

Step	Procedure	Press	Display
1	Enter the number of the task in which changes are to be made	3, D	3.
2	Enter the original value for $P(d_3)$	0.3, A	0.3
3	Enter $E(t_r)$*	2, 2^{nd}, B'	2.
4	Execute for P(I)	E	.906990599**

To change any other response parameters, P(C) or $\sigma(t_r)$, simply enter the change and press the appropriate user-defined key. Changes may be made at any time prior to program execution. To display current response data, recall the appropriate storage register as listed in Appendix B, i.e., press [RCL] 05 to display $E(t_r)$.

*For changes in P(C), $E(t_r)$, and $\sigma(t_r)$, enter changes following the instructions given on page 18.

**Final result.

IV. HP-67 OPERATING PROCEDURES

The HP-67 hand-held programmable calculator is shown in Figure 3. Each key on the keyboard can perform as many as four different functions. One function is indicated on the flat plane of the key face, while the second is printed in black on the slanted face of the key. The third and fourth functions are indicated by printed symbols in gold and blue, respectively, below the key.

There are three prefix keys, [f], [g], and [h]. By pressing one of these prefix keys before pressing a function key, the user can select the function printed on the slanted key face or one of the functions printed in gold or blue below the function key. These functions are selected in the following manner:

1. To select the function printed on the flat plane of a function key, simply press the key.
2. To select the function printed in black on the slanted key face, first press the black [h] prefix key, then press the function key.
3. To select the function printed in gold below the function key, first press the gold [f] prefix key, then press the function key.
4. To select the function printed in blue below the function key, first press the blue [g] prefix key, then press the function.

   For example, to activate the [x⇆y] function, first press the prefix key [h], then [x⇆y] which is on the slanted face of the [7] key. In the following discussion, all entries will include the prefix key and the function desired, e.g., [h] [x⇆y].

Programming the Calculator

The HP-67 calculator can be programmed by either manually entering the program steps listed in Appendix D or reading the contents of a pre-recorded magnetic card into the calculator.

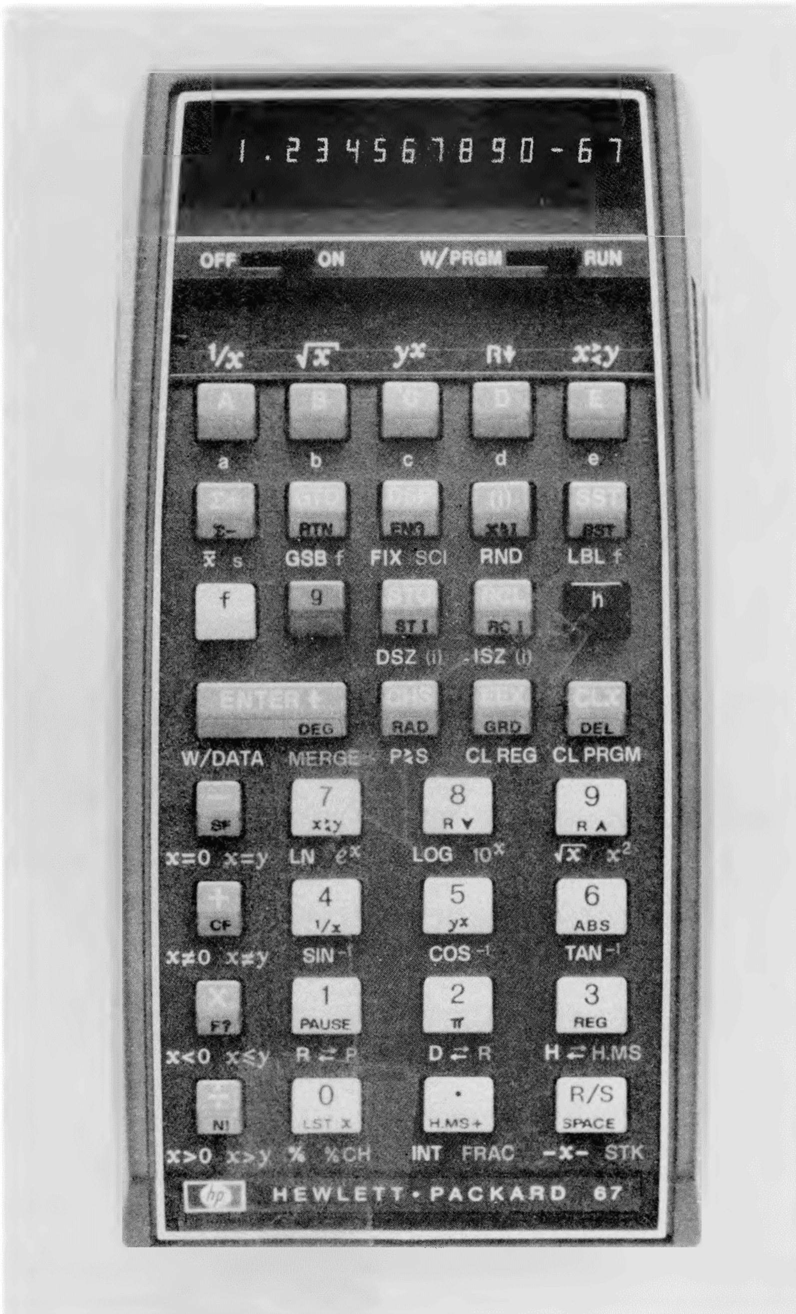


Figure 3. The HP-67 Calculator

In order to read the program from a magnetic card, turn on the calculator, slide the W/PRGM-RUN switch to RUN, read the first side of the card (the display will show "Crd" prompting the user to read the other side of the magnetic card), and then read the second side of the card.

Data Entry

Data entry consists of initializing the program, entering the response data, and entering the adversary task data. The program is initialized by pressing [A] and waiting for the calculator to stop. This procedure clears the storage registers and sets the internal flags.

The following example will be used to illustrate the Improved EASI Program for the HP-67 calculator. The path chosen for analysis is illustrated in Figure 4. This path contains the following adversary sequence:

1. The adversary penetrates the boundary fence, t_1, crosses the open area, t_2 and t_3, to the building door (where the adversary may be detected by Sensor 1, which is assumed to be halfway between the fence and the door).
2. The adversary penetrates the building door, t_4, which is protected by Sensor 2.
3. The adversary travels through the building and reaches the door to the Material Access Area (MAA), t_5.
4. The adversary opens the door to the MAA, t_6, which is protected by Sensor 3.
5. The adversary obtains the special nuclear material (SNM) and exits the MAA, t_7, travels down the hall, and exits the external door, t_8, (where an SNM detector may detect the SNM, Sensor 4).
6. After exiting the building, the adversary crosses the open area, t_9 and t_{10}, where he may be detected by the CCTV, Sensor 5 (same as Sensor 1).
7. The adversary then exits through the security fence and escapes, t_{11}.

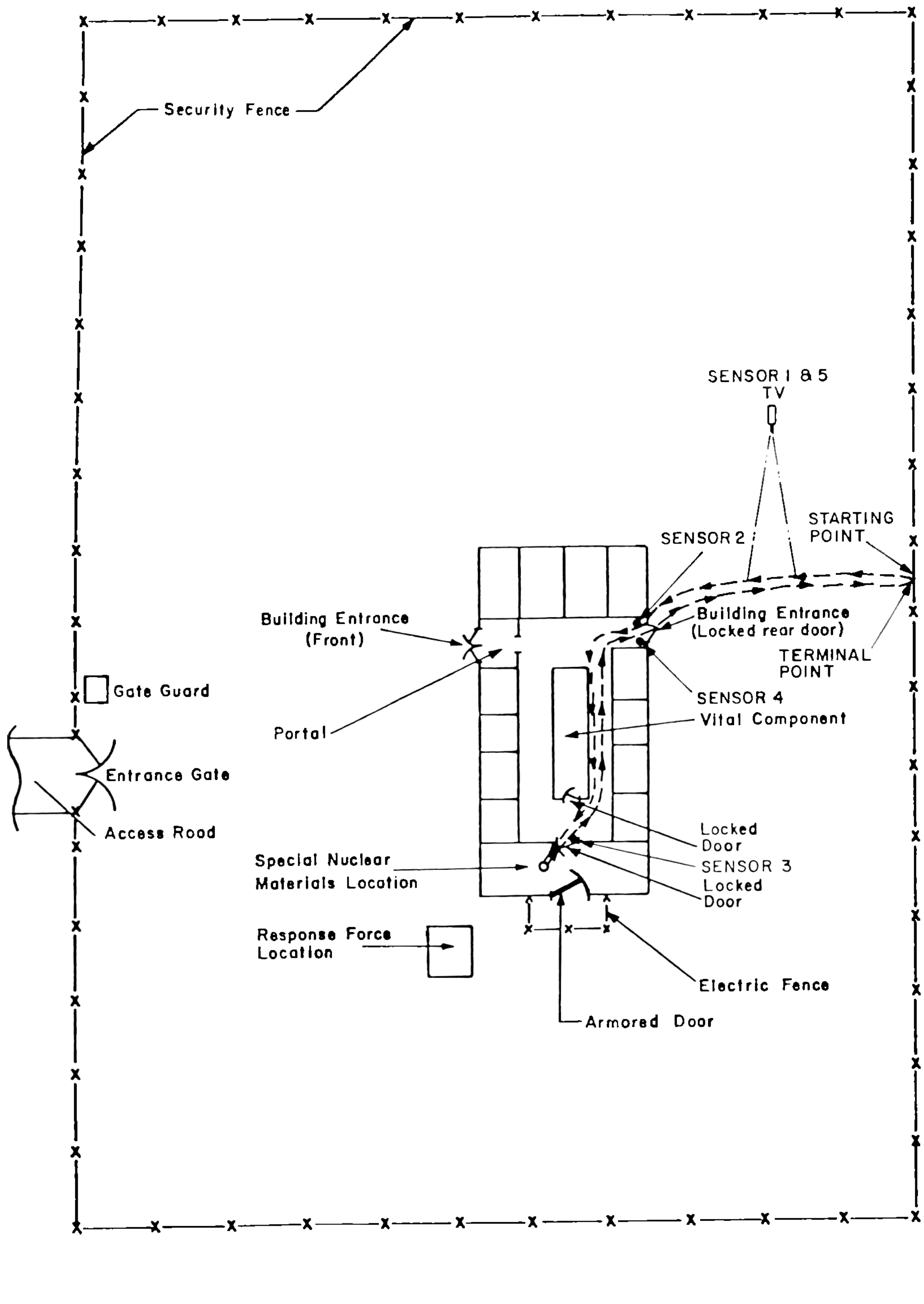
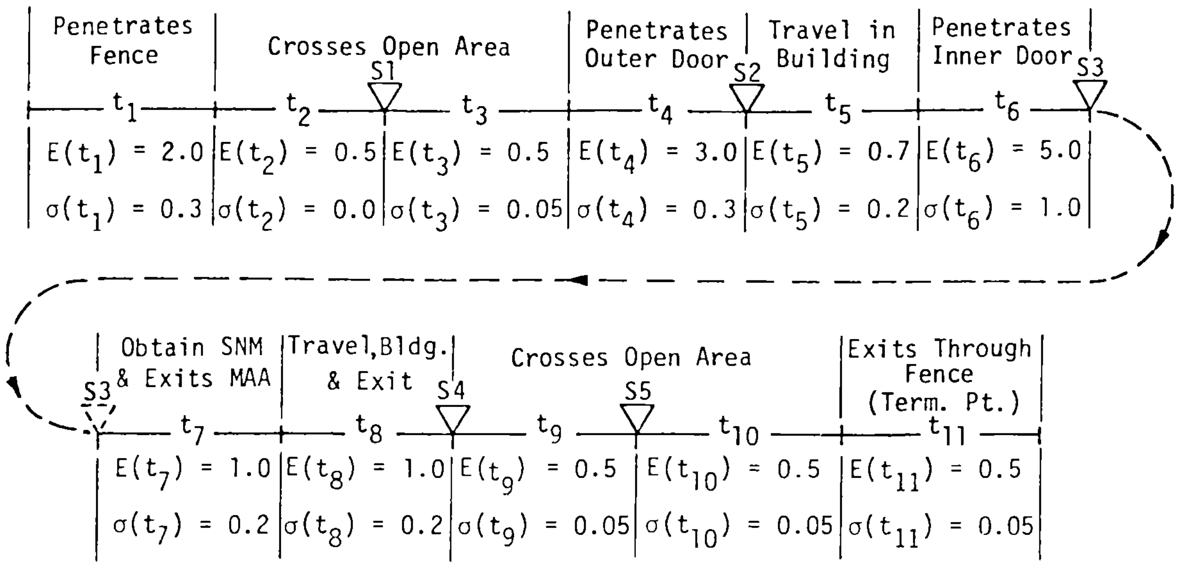


Figure 4. Adversary Path Used for HP-67 Example

The adversary time-sequence path is shown below:



NOTES:

1. There are five alarms with the following probabilities of detection: S1 = 0.3, S2 = 0.95, S3 = 0.9, S4 = 0.65, and S5 = 0.3. (It is assumed that both door sensors were disabled upon entry and they were not operative for the exit path.)
2. The probability of communication is 0.9.
3. The response force mean time, $E(t_r)$, is 4 minutes with a standard deviation $\sigma(t_r)$ of 0.5 minute.

The response force data are entered as follows:

Step	Procedure	Press	Display
1	Enter probability of communication, P(C)	0.9, Enter	0.900000000
2	Enter expected response time, $E(t_r)$	4.0, Enter	4.000000000
3	Enter standard deviation of response time, $\sigma(t_r)$	0.5, A	0.400005090*

Wait for display to blink once before continuing.

*Packed data.

P(C) must be less than 0.995 and both $E(t_r)$ and $\sigma(t_r)$ must be less than 99.995. If these limits are violated, the display will show "Error." Press [CLX] and enter acceptable data. Only two digits to the right of the decimal point are stored in the calculator. If data with more than two digits to the right of the decimal point are entered, internal rounding occurs. <u>This two-digit restriction applies only to the storage of input data</u>. Calculations are made using the full capacity of the calculator. If data have been entered correctly, the calculator stops with 10 digits displayed and formatted as shown in Figure 5.

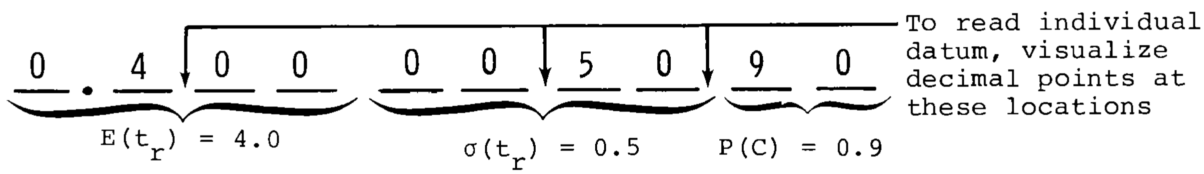


Figure 5. Packed Data Format

The adversary tasks are numbered in chronological order. Data related to these tasks are input as follows:

1. Enter the number of tasks and press [B] . When the calculator stops, 1.000000000 is displayed, prompting the user to input data for the first task. A maximum of 22 tasks is allowed. If this number is exceeded, "Error" is displayed. Press [CLX] and reenter the number of tasks.
2. Enter data for Task 1 as follows:

<u>Key in Value for</u>	<u>Press</u>
P(d)	[Enter]
$E(t_1)$	[Enter]
$\sigma(t_1)$	[C]

   The calculator stops briefly with t_1, $\sigma(t_1)$, P(d) displayed in the same format as described above, then resumes running and stops with 2.000000000 displayed, prompting the user to input data for Task 2.
3. Step 2 is repeated for Task 2, Task 3, etc. Remember that sensors are assumed to be located at the beginning of tasks.

If there is no sensor, enter zero for P(d). P(d) must be less than 0.995 and $E(t_r)$ and $\sigma(t_r)$ must be less than 99.995, otherwise "Error" is displayed. If this happens, press [CLX] and then [h] [RCI]. The integer part of the number displayed is the number of the task for which there was an input error. Return to Step 2 and input acceptable data for this task. Internal rounding to two places occurs as described above.

4. When data for all tasks have been entered, 0.000000000 is displayed.

The adversary task data for the example shown in Figure 4 would be input as follows:

Step	Procedure	Press	Display
4	Enter number of tasks	11,B	1.000000000
	Display prompting first task (tasks are entered in chronological order)		
5	Task 1:		
	Enter probability of detection, P(d)	0.0, Enter	0.000000000
	Enter mean time to complete Task 1, $E(t_1)$	2.0, Enter	2.000000000
	Enter standard deviation of t_1, $\sigma(t_1)$	0.3, C	0.200003000* then 2.000000000 (prompting Task 2)
6	Task 2:		
	$P(d_2)$	0.0, Enter	0.000000000
	$E(t_2)$	0.5, Enter	0.500000000
	$\sigma(t_2)$	0.0, C	0.050000000* then 3.000000000
7	Task 3:		
	$P(d_3)$ (Sensor 1)	0.3, Enter	0.300000000
	$E(t_3)$	0.5, Enter	0.500000000
	$\sigma(t_3)$	0.05, C	0.050000530* then 4.000000000

*Packed data.

Step	Procedure	Press	Display
8	Task 4:		
	P(d_4)	0.0, Enter	0.000000000
	E(t_4)	3.0, Enter	3.000000000
	σ(t_4)	0.3, C	0.300003000* then 5.000000000
9	Task 5:		
	P(d_5) (Sensor 2)	0.95, Enter	0.950000000
	E(t_5)	0.7, Enter	0.700000000
	σ(t_5)	0.2, C	0.070002095* then 6.000000000
10	Task 6:		
	P(d_6)	0.0, Enter	0.000000000
	E(t_6)	5.0, Enter	5.000000000
	σ(t_6)	1.0, C	0.500010000* then 7.000000000
11	Task 7:		
	P(d_7) (Sensor 3)	0.9, Enter	0.900000000
	E(t_7)	1.0, Enter	1.000000000
	σ(t_7)	0.2, C	8.100002090* then 8.000000000
12	Task 8:		
	P(d_8)	0.0, Enter	0.000000000
	E(t_8)	1.0, Enter	1.000000000
	σ(t_8)	0.2, C	0.100002000* then 9.000000000
13	Task 9:		
	P(d_9) (Sensor 4)	0.65, Enter	0.650000000
	E(t_9)	0.5, Enter	0.500000000
	σ(t_9)	0.05, C	0.050000565* then 10.000000000
14	Task 10:		
	P(d_{10}) (Sensor 5)	0.3, Enter	0.300000000
	E(t_{10})	0.5, Enter	0.500000000
	σ(t_{10})	0.05, C	0.050000530* then 11.000000000

*Packed data.

Step	Procedure	Press	Display
15	Task 11:		
	$P(d_{11})$	0.0, Enter	0.000000000
	$E(t_{11})$	0.5, Enter	0.500000000
	$\sigma(t_{11})$	0.05, C	0.500005000* then 0.000000000

0.000000000 indicates all tasks are entered.

Program Execution

After all data have been entered, press [E] to calculate the probability of interruption. The calculation begins with the last task first, then the next to last task, etc. The calculator pauses to display the results of each cumulative calculation which is the probability of interruption for the tasks considered to that point. These pauses can be extended indefinitely by pressing [R/S] before the calculation is resumed. Pressing [R/S] again continues the calculation.

When the calculation for all tasks has been completed, the calculator displays the probability of interruption with a blinking decimal point. To calculate the probability of interruption to the terminal point, execute Step 16, shown below.

Step	Procedure	Press	Display
16	Calculate probability of interruption	E	0.909935204

The intermediate results displayed when calculating the probability of interruption indicate the effect of each sensor and task starting from the last and working to the first. At any time after entering data for a task, the probability of interruption for the tasks entered to that point can be calculated by pressing [E]. Intermediate results displayed have the same meaning as indicated above if "last task" is interpreted as "last task entered." After the calculation is complete (blinking decimal), press [B] and the calculator will display the number of the next task and data entry can be resumed.

---

*Packed data.

Data Changes

Response data and adversary task data can be recalled for observation or data changes. To recall the response data, enter zero and press [D]. The current response data are briefly displayed in usual format, then 0.000000000 is displayed. The zero and response data can be interchanged by pressing [h] [x⇄y]. To enter new response data, repeat the input steps for the response data. If, and only if, response data are changed before all data have been entered, press [B] to display the next task number and data entry may be resumed.

The steps necessary to recall the response data for the example and to change the expected response time from 4 minutes to 2 minutes are shown below. The execution of the program using this new data is initated by Step 20.

Step	Procedure	Press	Display
17	Recall response data	0, D	0.400005090*
18	To display response data	h, x⇄y	0.400005090*
19	Change the $E(t_r)$ from 4 minutes to 2 minutes. (All response data reentry.)	0.9, Enter	0.900000000
		2.0, Enter	2.000000000
		0.5, A	0.200005090*
20	Execute program with new response data	E	0.980750272

To recall task data, enter number of the task and press [D]. Current data for this task are briefly displayed in the usual format and then the task number is displayed. Current data and task number can be alternately displayed using [h] [x⇄y]. To input new data, repeat the steps used for task data input. The calculator stops with the new data displayed. If, and only if, task data are changed before all data have been entered, press [B] to display the number of the next task and data entry may be resumed. If all task data are already entered, do not press [B]. Press [E] for results.

---

*Packed data.

V. TI-59 OPERATING PROCEDURES WITHOUT INPUT DATA STORAGE

The following operating instructions are for a program which will permit TI-59 users to essentially follow the SR-52 instructions given for the examples in the EASI user's guide (Reference 2). To calculate results for any data changes, the user is required to reenter all of the data. The TI-59 program for EASI without input data storage must be used. Do not use the Improved EASI Program. The specific example presented below uses input data for Example 1 of Reference 2.

Step	Procedure	Press	Display
1	Read in card*	1, or 0	1
2	Initialize program	E	0
3	Enter expected response time, $E(t_r)$	4, 2^{nd}, A'	4
4	Enter standard deviation of response time, $\sigma(t_r)$	0.16, 2^{nd}, B'	0.0256
5	Enter probability of communication, P(C)	0.9, 2^{nd}, C'	0.9
6	Enter expected time for Task 7, $E(t_7)$--closest to terminal point	0.1, A	0.1
7	Enter standard deviation for Task 7, $\sigma(t_7)$	0.02, B	0.004
8	Enter sensor probability of detection P(d) for S3	0.97, C	1.2131223-18**
9	Enter expected time for Task 6, $E(t_6)$	3, A	3
10	Enter standard deviation for Task 6, $\sigma(t_6)$	0.3, B	0.09
11	Enter expected time for Task 5, $E(t_5)$	0.5, A	0.5
12	Enter standard deviation for Task 5, $\sigma(t_5)$	0.1, B	0.01
13	Enter sensor probability of detection P(d) for S2	0.97, C	0.1[illegible]0440888**

*If the TI-59 has been turned off, the EASI program must be reentered. If the TI-59 has not been turned off, but the program is loaded, press the [E] button and proceed with Step 3.

**Blank for a few seconds before the number is displayed; do not press another key until a number appears on the display.

Step	Procedure	Press	Display
14	Enter expected time for Task 4, $E(t_4)$	3, A	3
15	Enter standard deviation for Task 4, $\sigma(t_4)$	0.3, B	0.09
16	Enter expected time for Task 3, $E(t_3)$	1.0, A	1
17	Enter standard deviation for Task 3, $\sigma(t_3)$	0.2, B	0.04
18	Enter sensor probability of detection P(d) for S1	0.3, C	0.3517906773*

NOTES:

1. Adversary times and sensors are entered in order from the terminal point, not the starting point.
2. The times for $E(t_2)$ and $E(t_3)$ were based on the assumption that the sensor point of detection was halfway (in time) between the fence and the door.
3. Adversary times which are closer to the starting point than the first sensor are not part of the solution.

*This number is the probability of interruption.

VI. CONCLUSIONS

New and improved programs for EASI have been documented for the Hewlett-Packard and Texas Instruments programmable calculators. These programs provide a more convenient and less error-prone method for performing sensitivity analyses utilizing EASI. The intent of this report was not to provide a series of illustrative examples on how to use EASI, but solely to provide and document the improved EASI programs. New users of EASI are referred to the user's guide (Reference 2) for illustrative examples and details on the EASI method.

VII. REFERENCES

1. H. A. Bennett, The "EASI" Approach to Physical Security Evaluation, SAND76-0500, Sandia Laboratories, Albuquerque, New Mexico, January 1977.

2. H. A. Bennett, User's Guide for Evaluating Physical Security Capabilities of Nuclear Facilities by the EASI Method, SAND77-0082, Sandia Laboratories, Albuquerque, New Mexico, June 1977.

3. D. W. Sasser, EASI on the HP-25, HP-65, and HP-67, SAND76-0597, Sandia Laboratories, Albuquerque, New Mexico, May 1977.

APPENDIX A

The EASI Mathematical Methodology

APPENDIX A

The EASI Mathematical Methodology

The EASI method calculates the probability of interruption of an adversary action sequence aimed at theft or sabotage. This is the probability that the response force will be notified when there is sufficient time remaining in the sequence for the force to respond. The notification of the response force is called an alarm and the probability of alarm is

$$P(A) = P(D)P(C) \tag{1}$$

where P(D) = probability of detection
P(C) = probability of communication to the response force.

In the case of a single detection sensor (or other possible means of detection), the probability of an adversary action sequence interruption is given by

$$P(I) = P(R|A)P(A) \tag{2}$$

where P(R|A) = probability of response force arrival prior to the end of the adversary's action sequence, given an alarm.

An adversary action sequence takes place along a path consisting of a starting point, a sequence of detection sensors, transit and barrier delays, and a terminal point. The transits and barriers can be thought of as tasks the adversary must perform. It is assumed that detection sensors are located only at the beginnings of tasks.

If t_a is the time remaining for the adversary to reach the terminal point when a sensor activates, and t_r is the response time of the security force, then for adversary interruption it is necessary that

$$t_a - t_r \geq 0 \tag{3}$$

The random variables t_a and t_r are assumed to be independent and normally distributed* and thus the random variable

$$x = t_a - t_r$$

is normally distributed with mean

$$\mu_x = E(t_a - t_r) = E(t_a) - E(t_r)$$

variance

$$\sigma_x^2 = var(t_a - t_r) = var(t_a) + var(t_r)$$

and

$$P(R|A) = P(x \geq 0) = \int_0^\infty \frac{1}{\sqrt{2\pi\sigma_x^2}} \exp\left[- \frac{(x - \mu_x)^2}{2\sigma_x^2} \right] dx \qquad (4)$$

In EASI P(R|A) is approximated by

$$P(R|A) \cong \frac{\exp(1.7\mu_x/\sigma_x)}{1 + \exp(1.7\mu_x/\sigma_x)} \qquad (5)$$

Since the method is concerned with the time remaining in the sequence, evaluation of $E(t_a)$ and $var(t_a)$ at point p along a path of interest must be with respect to the terminal point. The penetration time through each barrier and the transit time between barriers are considered to be random variables with values corresponding to the level of adversary resources. Then, the expected time from any point p to the terminal point n is

$$E(t_a) \text{ at point } p = \sum_{i=p+1}^{n} E(t_i)$$

---

*The normal distribution requirement may be approximated by letting t_a and t_r be sums of random variables which satisfy the conditions of the Central Limit Theorem.

where

$$E(t_i) = \text{the expected time to perform Task } i$$

Assuming each task to be independent, the variance of the path time remaining between point p and the terminal point n is

$$\text{Var}(t_a) \text{ at point } p = \sum_{i=p+1}^{n} \text{var}(t_i)$$

For two or more sensors the conditional probability of response force arrival, $P(R|A)$, for each sensor must be calculated as previously described. Then the cumulative probability of sequence interruption calculated along the adversary's path from the starting point is

$$P(I) = P(R|A_1)P(A_1) + \sum_{i=2}^{n} P(R|A_i)P(A_i) \prod_{j=1}^{i-1} Q(A_j) \qquad (6)$$

where

$$Q(A_j) = 1 - P(A_j)$$

APPENDIX B

Improved EASI Program Listing for TI-59

APPENDIX B

Improved EASI Program Listing for TI-59

Slide the ON-OFF switch to the ON position, repartition the data memory by pressing [9] [2nd] [Op] [1] [7], press [LRN], and then key in the following:

Key	Display		Key	Display	
LBL	000	76	20	027	20
A	001	11	RCL	028	43
ST*	002	72	00	029	00
02	003	02	R/S	030	91
R/S	004	91	LBL	031	76
LBL	005	76	E'	032	10
B	006	12	CMS	033	47
ST*	007	72	CLR	034	25
03	008	03	R/S	035	91
R/S	009	91	LBL	036	76
LBL	010	76	B'	037	17
C	011	13	STO	038	42
ST*	012	72	05	039	05
04	013	04	R/S	040	91
PAU	014	66	LBL	041	76
RCL	015	43	C'	042	18
00	016	00	X^2	043	33
EQ	017	67	STO	044	42
00	018	00	06	045	06
30	019	30	R/S	046	91
OP	020	69	LBL	047	76
22	021	22	A'	048	16
OP	022	69	STO	049	42
23	023	23	07	050	07
OP	024	69	R/S	051	91
24	025	24	LBL	052	76
OP	026	69	D'	053	19

NOTE: Key code taken from printer listing. For actual key sequence see TI-59 Owner's Manual, Page VI-6.

Key	Display		Key	Display	
STO	054	42	GTO	089	61
01	055	01	D	090	14
X≷T	056	32	INV	091	22
2	057	02	STF	092	86
5	058	05	01	093	01
INV	059	22	0	094	00
GE	060	77	STO	095	42
09	061	09	08	096	08
59	062	59	STO	097	42
1	063	01	09	098	09
3	064	03	STO	099	42
STO	065	42	10	100	10
02	066	02	RC*	101	73
+	067	85	03	102	03
RCL	068	43	SUM	103	44
01	069	01	09	104	09
=	070	95	RC*	105	73
STO	071	42	04	106	04
03	072	03	X^2	107	33
+	073	85	SUM	108	44
RCL	074	43	08	109	08
01	075	01	RCL	110	43
=	076	95	07	111	07
STO	077	42	x	112	65
04	078	04	RC*	113	73
1	079	01	02	114	02
STO	080	42	=	115	95
00	081	00	STO	116	42
R/S	082	91	11	117	11
LBL	083	76	CP	118	29
E	084	15	EQ	119	67
STF	085	86	01	120	01
01	086	01	75	121	75
RCL	087	43	RCL	122	43
01	088	01	08	123	08

Key	Display		Key	Display	
+	124	85	=	159	95
RCL	125	43	+	160	85
06	126	06	RCL	161	43
=	127	95	10	162	10
$\sqrt{X}$	128	34	x	163	65
1/X	129	35	(	164	53
x	130	65	1	165	01
(	131	53	-	166	75
RCL	132	43	RCL	167	43
09	133	09	11	168	11
-	134	75	)	169	54
RCL	135	43	=	170	95
05	136	05	STO	171	42
)	137	54	10	172	10
x	138	65	PAU	173	66
1	139	01	PAU	174	66
.	140	93	INV	175	22
7	141	07	DSZ	176	97
=	142	95	00	177	00
INV	143	22	01	178	01
LNX	144	23	89	179	89
(	145	53	OP	180	69
STO	146	42	32	181	32
12	147	12	OP	182	69
÷	148	55	33	183	33
(	149	53	OP	184	69
1	150	01	34	185	34
+	151	85	GTO	186	61
RCL	152	43	01	187	01
12	153	12	01	188	01
)	154	54	RCL	189	43
)	155	54	10	190	10
x	156	65	R/S	191	91
RCL	157	43	LBL	192	76
11	158	11	D	193	14

Key	Display		Key	Display	
STO	194	42	IFF	214	87
00	195	00	01	215	01
+	196	85	00	216	00
1	197	01	91	217	91
2	198	02	RCL	218	43
=	199	95	01	219	01
STO	200	42	X≷T	220	32
02	201	02	RCL	221	43
+	202	85	00	222	00
RCL	203	43	R/S	223	91
01	204	01	RC*	224	73
=	205	95	02	225	02
STO	206	42	R/S	226	91
03	207	03	RC*	227	73
+	208	85	03	228	03
RCL	209	43	R/S	229	91
01	210	01	RC*	230	73
=	211	95	04	231	04
STO	212	42	R/S	232	91
04	213	04			

USER DEFINED KEYS		DATA REGISTERS			
A	$P(d_i)$	0	Current task no.	10	P(I)
B	$E(t_i)$	1	Total no. of tasks (n)	11	$P(A_i)$
C	$\sigma(t_i)$	2	Register index $P(d_i)$	12	Used
D	Task no. for data change	3	Register index $E(t_i)$	13	$P(d_i)$
E	Execute program	4	Register index $\sigma(t_i)$	13+n	$E(t_i)$
A'	P(C)	5	$E(t_r)$	13+2n	$\sigma(t_i)$
B'	$E(t_r)$	6	$Var(t_r)$		
C'	$\sigma(t_r)$	7	P(C)		
D'	Total task no. (n)	8	$\sum Var(t_i)$		
E'	Initialize	9	$\sum E(t_i)$		

FLAGS	USED 1	2	3	4	5

APPENDIX C

EASI Program Listing for TI-59 without Input Data Storage

APPENDIX C

EASI Program Listing for TI-59 without Input Data Storage Capability

Slide the ON-OFF switch to the ON position, press [LRN], and then key in the following:

Key	Display		Key	Display	
LBL	000	76	LBL	026	76
E	001	15	B'	027	17
CMS	002	47	X^2	028	33
CLR	003	25	STO	029	42
R/S	004	91	07	030	07
LBL	005	76	R/S	031	91
A	006	11	LBL	032	76
SUM	007	44	C	033	13
01	008	01	x	034	65
R/S	009	91	RCL	035	43
LBL	010	76	03	036	03
B	011	12	=	037	95
X^2	012	33	STO	038	42
SUM	013	44	04	039	04
02	014	02	RCL	040	43
R/S	015	91	07	041	07
LBL	016	76	+	042	85
C'	017	18	RCL	043	43
STO	018	42	02	044	02
03	019	03	=	045	95
R/S	020	91	$\sqrt{X}$	046	34
LBL	021	76	1/X	047	35
A'	022	16	x	048	65
STO	023	42	(	049	53
05	024	05	RCL	050	43
R/S	025	91	01	051	01

Key	Display		Key	Display	
-	052	75	)	072	54
RCL	053	43	)	073	54
05	054	05	x	074	65
)	055	54	RCL	075	43
x	056	65	04	076	04
1	057	01	=	077	95
.	058	93	+	078	85
7	059	07	RCL	079	43
=	060	95	08	080	08
INV	061	22	x	081	65
LNX	062	23	(	082	53
(	063	53	1	083	01
STO	064	42	-	084	75
06	065	06	RCL	085	43
÷	066	55	04	086	04
(	067	53	)	087	54
1	068	01	=	088	95
+	069	85	STO	089	42
RCL	070	43	08	090	08
06	071	06	R/S	091	91

USER DEFINED KEYS		DATA REGISTERS	
A	$E(t_i)$	1	$\sum E(t_i)$
B	$\sigma(t_i)$	2	$\sum Var(t_i)$
C	$P(d_s)$	3	P(C)
E	Initialize program	4	$P(A_s)$
A'	$E(t_r)$	5	$E(t_r)$
B'	$\sigma(t_r)$	6	Used
C'	P(C)	7	$Var(t_r)$
		8	P(I)
FLAGS	NONE USED		

APPENDIX D

Improved EASI Program Listing for HP-67

Key		Display		
fLBLA	001	31	25	11
hF?2	002	35	71	02
GTO4	003		22	04
fCLREG	004		31	43
fP⇄S	005		31	42
fCLREG	006		31	43
hCF0	007	35	61	00
hSF2	008	35	51	02
gLBLc	009	32	25	13
EEX	010			43
7	011			07
x	012			71
gFRAC	013		32	83
hRTN	014		35	22
fLBL4	015	31	25	04
hSF2	016	35	51	02
fLBLC	017	31	25	13
DSP2	018		23	02
fRND	019		31	24
fGSB2	020	31	22	02
EEX	021			43
5	022			05
÷	023			81
STO(i)	024		33	24
hR↓	025		35	53
fRND	026		31	24
fGSB2	027	31	22	02
EEX	028			43
1	029			01
÷	030			81
STO+(i)	031	33	61	24
hR↓	032		35	53
fRND	033		31	24
1	034			01
gx>y	035		32	81
GTO3	036		22	03
GTO9	037		22	09
fLBL3	038	31	25	03
hR↓	039		35	53
EEX	040			43
7	041			07
÷	042			81
STO+(i)	043	33	61	24
DSP9	044		23	09
RCL(i)	045		34	24
hPAUSE	046		35	72
hRCI	047		35	34
gFRAC	048		32	83
hSTI	049		35	33
hR↓	050		35	53
hF?2	051	35	71	02
R/S	052			84
hRCI	053		35	34
fGSB7	054	31	22	07

Key	Display		
x	055		71
hSTI	056	35	33
fDSZ	057	31	33
GTOfd	058	22 31	14
hCF0	059	35 61	00
CLX	060		44
gLBLa	061	32 25	11
EEX	062		43
3	063		03
GTO8	064	22	08
gLBLb	065	32 25	12
EEX	066		43
3	067		03
x	068		71
gFRAC	069	32	83
EEX	070		43
4	071		04
fLBL8	072	31 25	08
x	073		71
fINT	074	31	83
fGSB7	075	31 22	07
÷	076		81
hRTN	077	35	22
fLBLB	078	31 25	12
hF?0	079	35 71	00
GTO6	080	22	06
2	081		02
3	082		03
gx≤y	083	32	71
GTO9	084	22	09
hSF0	085	35 51	00
hR▼	086	35	53
1	087		01
0	088		00
1	089		01
f%	090	31	82
hSTI	091	35	33
gLBLd	092	32 25	14
hRCI	093	35	34
fGSB7	094	31 22	07
ENTER	095		41
h $1/x$	096	35	62
+	097		61
x	098		71
1	099		01
+	100		61
hRCI	101	35	34
fINT	102	31	83
1	103		01
0	104		00
1	105		01
x	106		71
-	107		51
GTO0	108	22	00
fLBLE	109	31 25	15
hRCI	110	35	34
gFRAC	111	32	83
hF?0	112	35 71	00
fGSB5	113	31 22	05
1	114		01
.	115		83
0	116		00
1	117		01
x	118		71
hF?0	119	35 71	00
-	120		51
hSTI	121	35	33
RCL(i)	122	34	24
gGSBa	123	32 22	11
CHS	124		42

Key	Display			
STOE	125		33	15
RCL(i)	126		34	24
gGSBb	127	32	22	12
gX^2	128		32	54
STOD	129		33	14
hRCI	130		35	34
fGSB7	131	31	22	07
x	132			71
hSTI	133		35	33
CLX	134			44
gLBLe	135	32	25	15
RCL(i)	136		34	24
gGSBa	137	32	22	11
RCLE	138		34	15
+	139			61
STOE	140		33	15
hR▾	141		35	53
RCL(i)	142		34	24
gGSBb	143	32	22	12
gX^2	144		32	54
RCLD	145		34	14
+	146			61
STOD	147		33	14
hR▾	148		35	53
RCL(i)	149		34	24
gGSBc	150	32	22	13
fX=0	151		31	51
GTO1	152		22	01
RCL0	153		34	00
gGSBc	154	32	22	13
x	155			71
RCLE	156		34	15
RCLD	157		34	14
$f\sqrt{X}$	158		31	54
÷	159			81

Key	Display			
1	160			01
.	151			83
7	162			07
x	163			71
ge^x	164		32	52
1	165			01
hx≷y	166		35	52
+	167			61
hLSTX	168		35	82
hx≷y	169		35	52
÷	170			81
hx≷y	171		35	52
x	172			71
hLSTX	173		35	82
1	174			01
−	175			51
hR▴	176		35	54
x	177			71
−	178			51
hR▴	179		35	54
fLBL1	180	31	25	01
hR▾	181		35	53
hPAUSE	182		35	72
fDSZ	183		31	33
GTOfe	184	22	31	15
f-x-	185		31	84
hRTN	186		35	22
fLBLD	187	31	25	14
hRCI	188		35	34
hF?0	189	35	71	00
STOC	190		33	13
gFRAC	191		32	83
+	192			61
hSTI	193		35	33
RCL(i)	194		34	24

Key		Display		
hPAUSE	195		35	72
hx⇄y	196		35	52
fINT	197		31	83
hSF2	198	35	51	02
fLBL2	199	31	25	02
fGSB7	200	31	22	07
gx≤y	201		32	71
GTO9	202		22	09
hR▼	203		35	53
hRTN	204		35	22
fLBL5	205	31	25	05
hLSTX	206		35	82
STOC	207		33	13
gFRAC	208		32	83
fGSB7	209	31	22	07
x	210			71
ENTER	211			41
fINT	212		31	83
hRTN	213		35	22
fLBL6	214	31	25	06
hCF2	215	35	61	02
RCLC	216		34	13
fLBL0	217	31	25	00
hSTI	218		35	33
fINT	219		31	83
hRTN	220		35	22
fLBL7	221	31	25	07
EEX	222			43
2	223			02
hRTN	224		35	22

DATA REGISTERS

PRIMARY*		SECONDARY*	
0	$P(C)$, $E(t_r)$, $\sigma(t_r)$	0	$P(d_{10})$, $E(t_{10})$, $\sigma(t_{10})$
1	$P(d_1)$, $E(t_1)$, $\sigma(t_1)$	1	$P(d_{11})$, $E(t_{11})$, $\sigma(t_{11})$
2	$P(d_2)$, $E(t_2)$, $\sigma(t_2)$	2	$P(d_{12})$, $E(t_{12})$, $\sigma(t_{12})$
3	$P(d_3)$, $E(t_3)$, $\sigma(t_3)$	3	$P(d_{13})$, $E(t_{13})$, $\sigma(t_{13})$
4	$P(d_4)$, $E(t_4)$, $\sigma(t_4)$	4	$P(d_{14})$, $E(t_{14})$, $\sigma(t_{14})$
5	$P(d_5)$, $E(t_5)$, $\sigma(t_5)$	5	$P(d_{15})$, $E(t_{15})$, $\sigma(t_{15})$
6	$P(d_6)$, $E(t_6)$, $\sigma(t_6)$	6	$P(d_{16})$, $E(t_{16})$, $\sigma(t_{16})$
7	$P(d_7)$, $E(t_7)$, $\sigma(t_7)$	7	$P(d_{17})$, $E(t_{17})$, $\sigma(t_{17})$
8	$P(d_8)$, $E(t_8)$, $\sigma(t_8)$	8	$P(d_{18})$, $E(t_{18})$, $\sigma(t_{18})$
9	$P(d_9)$, $E(t_9)$, $\sigma(t_9)$	9	$P(d_{19})$, $E(t_{19})$, $\sigma(t_{19})$

USER DEFINED KEYS		DATA REGISTERS	
A	Initialization and response data	A	$P(d_{20})$, $E(t_{20})$, $\sigma(t_{20})$
B	Number of tasks and resume data entry	B	$P(d_{21})$, $E(t_{21})$, $\sigma(t_{21})$
C	Entering task data	C	$P(d_{22})$, $E(t_{22})$, $\sigma(t_{22})$
D	Data changes	D	$\sum\sigma^2(t_i) + \sigma^2(t_r)$
E	Execute program	E	$\sum E(t_i) - E(t_r)$
		I	Indexing register

FLAGS	0 USED	1	2 USED	3

Labels a, b, c, d, e, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 are used internally.

*It is very important that the primary and secondary data registers not be interchanged.

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