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ANALYSIS OF EFFECTIVENESS OF CIVIL DEFENSE PROGRAM ELEMENTS.(U)
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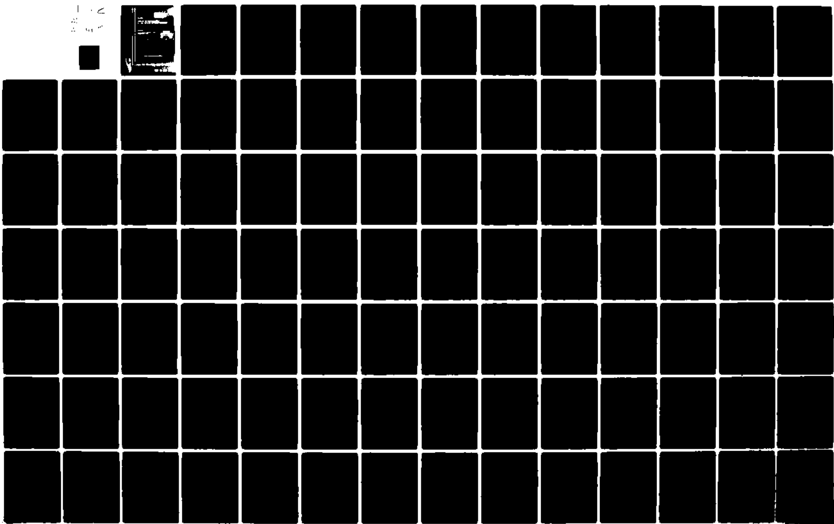

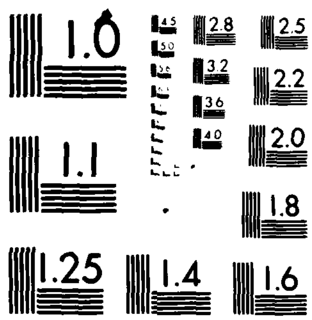

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Final Report

ANALYSIS OF EFFECTIVENESS OF CIVIL DEFENSE PROGRAM ELEMENTS

Prepared for:

Federal Emergency Management Agency
Washington, DC 20472

Contract: DCPA01-79-C-0247

by:

John F. Devaney
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June 1980

FEMA REVIEW NOTICE

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A methodology is documented that allows the analysis of a civil defense program for which estimates of overall performance have been made using the Population Defense (POPDEF) and Program Analysis (PAM) models so as to ascertain the relative contributions of the elements of the program to its effectiveness. The method is applied to a candidate program and estimates of the program in terms of added survival, total and uninjured. The relative effectiveness of program elements, individually and in selected combinations, is given in terms of cost per survivor added.

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DETACHABLE SUMMARY

ANALYSIS OF EFFECTIVENESS OF CIVIL DEFENSE PROGRAM ELEMENTS

John F. Devaney and Walmer E. Strope
Center for Planning and Research, Inc.
Contract No. DCPA01-79-C-0247; June 1980

A methodology has been developed for estimating the effectiveness of the elements of a civil defense program individually and in selected combinations, without the necessity of repeated application of the Population Defense (POPDEF) model. This methodology uses the survival estimates calculated for the program in POPDEF and the Program Analysis (PAM) model. It is an extension to, not a substitute for, the POPDEF and PAM methodology.

This new methodology ascertains which of the civil defense capabilities, as represented by POPDEF input factors, contribute substantially all of the survival, total and uninjured, estimated by the POPDEF calculations. It then produces a simplified algorithm employing these input factors as a substitute for the POPDEF algorithm. New values for the selected input factors are calculated in the PAM model by substituting input estimates for each program element that are appropriate for the evaluation being undertaken. When these values are substituted in the simplified algorithm, estimates of survival, total and uninjured, can be calculated manually, easily and quickly. This allows analysis of the effectiveness of the program in terms of the effectiveness of each of its elements. It also allows estimates of effectiveness for varied combinations of the elements and for varied scope of the individual elements, all within the limits imposed by the original program design. It cannot account for changes of such scope as to constitute a new, different program design.

An indication of how well the simplified algorithm can substitute for POPDEF is given in Table S-1, which gives the estimates calculated by both methods for six different postures of Program D Prime.

An example of the results of a program analysis is shown in Table S-2, which gives the total survival added by Program D Prime in the Relocated mode over that for the current capability when subjected to a relatively heavy military/industry attack. Added survival is shown in terms of fraction of the total preattack population for each program element and for each of the capabilities represented by the POPDEF inputs selected for the simplified algorithm: FCR (fraction relocated), FIS (fraction in assigned

shelters), FPF (fraction in improved fallout posture), and FER (fraction achieving remedial movement after emerging from shelter).

Table S-1

COMPARISON OF ESTIMATES
(Survival in Fractions of Population)

Posture	Uninjured Simplified	Uninjured POPDEF	Total Simplified	Total POPDEF
No relocation	0.38	0.36	0.48	0.48
In-place	0.48	0.47	0.58	0.58
No D & C	0.49	0.50	0.64	0.63
Current D & C	0.60	0.60	0.71	0.71
Relocated	0.66	0.66	0.75	0.76
Full relocation	0.75	0.75	0.84	0.84

Table S-2

TOTAL SURVIVAL ADDED BY PROGRAM D PRIME-RELOCATED
(Above Current Capability Maintained)

Program Element	FCR	FIS	FPF	FED	Total
Relocations Plans	0.114				0.114
Shelters		0.075			0.075
D & C	0.023	0.003	0.003	0.015	0.044
Wardens	0.014	0.001	0.001	0.022	0.038
Shelter stocks		0.030			0.030
Operations plans	0.014	0.001	0.001	0.004	0.020
Exercises	0.006	0.001		0.003	0.010
Citizen training	0.003	0.003		0.003	0.009
RADEF monitors			0.005	0.001	0.006
Ventilation kits		0.004			0.004
Emergency broadcast				0.001	0.001
RADEF instruments			0.001		0.001
Total	0.174	0.118	0.011	0.049	0.352

The effectiveness of program elements in terms of cost per survivor added is demonstrated in Table S-3 for Program D Prime-Relocated. Survival is based on a projected mid-1980s population of 230 million. It is noted that, while the estimates of cost per survivor added give an indication of the relative effectiveness among the program elements, the high estimates of the last two signal the desirability of critical review of the treatment of these elements in the PAM model.

Table S-3

COST PER SURVIVOR ADDED - DRE
(FY 1981 Dollars)

	Uninjured		Total	
Program Element	Survival Added (millions)	Cost per Survival Added (dollars)	Survival Added (millions)	Cost per Survival Added (dollars)
Wardens	13.3	$ 2	8.7	$ 3
Relocation plans	23.0	10	26.2	9
Shelters	11.3	20	17.3	13
Operations plans	5.3	18	4.6	21
RADEF monitors	4.6	11	1.4	36
Citizen training	3.0	26	2.1	38
Shelter stocks	10.1	30	6.9	44
Exercises	2.8	36	2.3	43
D & C	14.3	38	10.1	54
Ventilation kits	1.6	85	0.9	150
Emergency broadcast	0.7	240	0.3	710
RADEF instruments	0.7	520	0.2	1,570
Total	90.7	25	81.0	29

An example of the result of a synthesis of the effectiveness estimates (as exemplified in Table S-2) for combinations of elements in group (packages) that have a common purpose is shown in Figure S-1. The packages contain:

A. Paper plans: Plans for relocating Risk populations and for their reception and care plus a capability to inform the public when relocation is directed.

B. Relocation effectiveness: Detailed relocation plans plus a capability to direct and control relocation operations.

C. Sheltering and warning: Plans for shelter production and use plus capabilities to warn the people, to inform them of actions they can take for their protection, and to direct and control the movement to shelter.

D. Attack operations: Capabilities for managing, directing, and controlling emergency operations in the event of attack.

E. Shelter endurance: Capabilities for improving the environment in the shelters and the supply of such essentials as water to obviate premature leaving.

When the estimates of survival for the elements in these packages are combined and the combined estimates are summed cumulatively, the estimated survival versus program cost appears as in Figure S-1. The slopes of the lines in the graph are generally indicative of cost effectiveness: the steeper the slope, the lower the cost per survivor added. However, it is noted that the packages do not represent a logical program schedule and therefore Figure S-1 is best viewed as demonstrative rather than substantive.

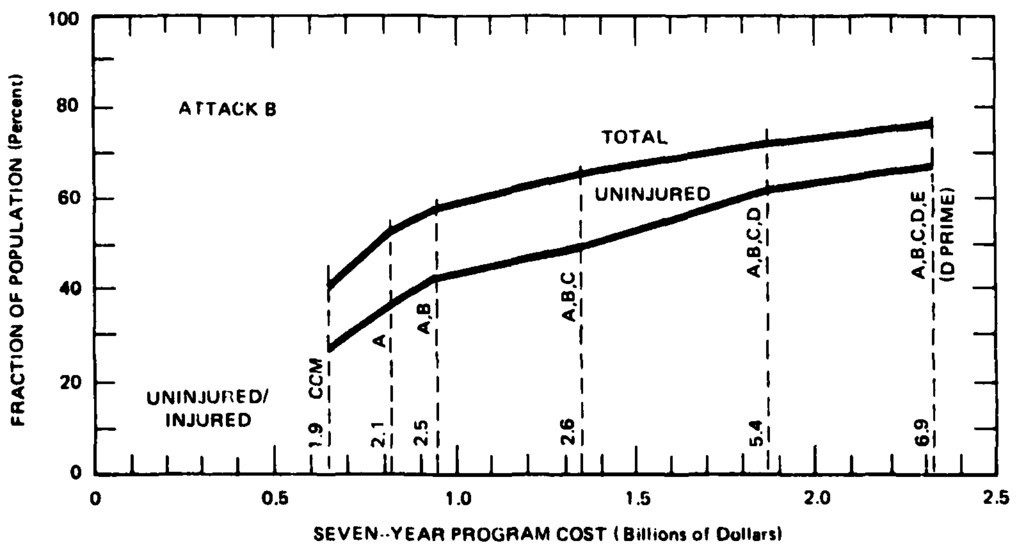

Figure S-1. PERFORMANCE OF PROGRAM D PRIME PACKAGES

Conclusions and Recommendations

The extension to the POPDEF/PAM methodology is an effective procedure for analyzing the effectiveness and cost-effectiveness of elements of a civil defense program. It is recommended that it be adopted. More detailed conclusions and recommendations are presented in the report.

ABSTRACT

A methodology is documented that allows the analysis of a civil defense program for which estimates of overall performance have been made using the Population Defense (POPDEF) and Program Analysis (PAM) models so as to ascertain the relative contributions of the elements of the program to its effectiveness. The method is applied to a candidate program and estimates of the program in terms of added survival, total and uninjured. The relative effectiveness of program elements, individually and in selected combinations, is given in terms of cost per survivor added.

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I. INTRODUCTION

Purpose

The purpose of this report is to record the results of an analysis of the contribution of the several elements of a proposed civil defense program to the expected performance of the deployed system, as measured by lives saved and injuries avoided. These results are intended to aid in achieving a balanced program design so that available resources can be applied to elements of greatest expected payoff. The work is based on and is an application of assessment methods previously reported.[1,2,3*] In addition, new model relationships are presented.

Scope

The work reported here was performed for the Defense Civil Preparedness Agency (now incorporated into the Federal Emergency Management Agency) under Contract No. DCPA01-79-C-0247, which contained the following scope of work:

A. **General.** The Contractor, in consultation and cooperation with the Government, shall furnish the necessary facilities, personnel, and such other services as may be required to perform cost-effectiveness analyses of civil defense program elements, using the techniques previously developed under Contract No. DCPA01-77-C-0223 as a basis for DCPA program design, so as to allocate available funds and effort to areas of greatest expected payoff.

B. **Specific Work and Services.** The Contractor shall perform specific work and services including but not limited to the following:

1. Devise, in cooperation with the Government, a set of nuclear attack options appropriate to the 1985-87 time frame for use in testing the design of civil defense programs.

2. Conduct a comprehensive series of casualty assessments, using the methodology previously developed and implemented at the DCPA computation facility, in which the performance characteristics of the elements of a civil defense program defined by the Government are varied over appropriate ranges, both individually and

*Superscripts refer to references listed following the concluding section of the report.

in combination, and determine the most cost-effective combination for a balanced civil defense system designed against the attack options of B1 above. Identify, by means of this effectiveness analysis, any program elements not included in the program design that would significantly improve potential effectiveness within the overall budget constraints of the program.

3. Explore the application of the casualty assessment methodology in scheduling the deployment of individual program element capabilities so as to maximize the expected performance of a civil defense program at any time during a deployment period of five to ten years.

4. Incorporate into the effectiveness methodology, and test the significance of, pertinent technical information and operational data that become available during calendar year 1979.

Limitations

The models used in this analysis, the Population Defense Model (POPDEF) and the Program Analysis Model (PAM), include all civil defense elements that contribute significantly to casualty reduction with the exception of medical care and some crisis relocation direction and control functions. Within these limitations, the adequacy of the results and the validity of conclusions based thereon are limited primarily by the quality of the data and estimates on which the model inputs are based. Most of the results make use of the "best" estimates made by expert panels and reported in Reference 3, except when particular program elements and element combinations are varied parametrically for analysis purposes.

The analysis is limited to a civil defense program defined by the Government and known as Program D Prime. This program introduces a capability to relocate a large proportion of people residing in areas presumed to be at high risk of being targeted to areas of lower risk. The representation of the relocated population distribution used to assess attack effects is not an accurate reflection of the likely distribution if the current basis for implementing Program D Prime is pursued. An associated limitation is that only one hypothetical attack appropriate to the 1985-1987 time frame is used in the analysis. This attack is the same attack as Attack B in Reference 3. The relationship of the characteristics of Program D Prime to the devising of suitable nuclear attack options is discussed in Appendix B. These limitations do not impinge significantly on the major thrust of the study effort; namely, the analysis of the relative contributions of program elements. Rather, they suggest that the measures of absolute performance under hypothetical attack should be judged in light of these limitations.

Overview

This introduction is the first of four sections of the report. Section II describes the methodology used in the analysis. The analysis of program elements is provided in Section III. The results and their implications are discussed and conclusions and recommendations are presented in Section IV. The report is supported by several appendices.

II. SIMPLIFIED METHODOLOGY

In the work of this study, a simplified method of calculating survival estimates was developed for use in analyzing the performance of program elements and in evaluating alternatives among them. The development of this method is described in the first part of this section. This development required a number of calculations using the PAM and POPDEF models, thus presenting the opportunity to observe them closely in practice. The latter part of this section presents comments on these observations.

Simplified Performance Calculations

In its present state of development,[2,3] the POPDEF/PAM produces performance estimates for use in evaluating alternative total civil defense programs. In the method, the Program Analysis Model (PAM) permits great detail in describing the civil defense program with respect to the location of people and their protection, planning, staffing and training, equipment, facilities, and so on. The Population Defense Model (POPDEF) produces estimates of survivors, injured and uninjured, in summary for program comparisons and in detail for use in analyzing program performance. This detail is appropriate for evaluation of alternative programs because it serves to enhance the validity of the estimates and of the comparative evaluations. (Readers unfamiliar with the POPDEF and PAM models and the terminology used should consult Appendix A.)

Effective program planning, however, requires evaluation not only of alternative total programs but also of alternative elements within a given program; for example, investment in monitor training vs. procurement of radiation measuring instruments. The POPDEF/PAM method can be used for this purpose but it is unwieldy. It requires introduction of PAM input estimates for each of the alternative elements, calculation of new PAM outputs, their introduction into POPDEF, and calculation of POPDEF estimates of numbers of survivors. This requires substantial effort and use of the FEMA computer, and tends to inhibit consideration of alternatives among program elements. It appears, then, that a simplified method is needed for producing performance estimates that are sufficiently valid for evaluating alternatives within a given overall civil defense program.

The method described below should fill this need. This method is predicated on the availability of PAM and POPDEF calculations for the total program and it must be emphasized that it is not a substitute for POPDEF/PAM in evaluating total programs.

The first step in formulating this simplified method was an analysis of the sensitivity of the POPDEF survival estimates to changes in the input factors. The objective was to ascertain which of the POPDEF input factors have the greatest potential for affecting the survival estimate. This potential was estimated by setting each input factor equal to zero in turn while keeping all of the others at their values for Program D Prime-Relocated (DRE). The calculations are described in Appendix C and the results are summarized in Table 1.

Table 1

EFFECT OF POPDEF INPUTS ON SURVIVAL ESTIMATES - DRE
(Fractions of Total Population - Attack B)

Factor Equal to Zero	Uninjured Survival		Total Survival	
	Estimate	Difference	Estimate	Difference
None	0.662	-	0.757	-
FCR	0.362	0.300	0.477	0.280
FIS	0.351	0.311	0.512	0.245
EML	0.656	0.006	0.755	0.002
FF	0.662	-	0.758	(0.001)
FR	0.659	0.003	0.747	0.010
FPF	0.637	0.025	0.747	0.010
FER	0.662	-	0.756	0.001
FWR	0.660	0.002	0.756	0.001
FVR	0.660	0.002	0.755	0.002
FER	0.552	0.110	0.699	0.058
		0.759		0.608
All	0.162	0.500	0.276	0.481

In Table 1, the values in the "estimate" columns are the fractions of the total population who would survive given Program D Prime except for the activity represented by the POPDEF input set equal to zero. For example, if none of the Risk population were to relocate (FCR = 0), 0.362 of the total population would survive uninjured and total survival, both uninjured and injured, would be 0.477. Similarly, if none of those persons trapped were rescued (FR = 0), uninjured survival would be 0.659 and total survival would be 0.747 of the entire population. When none of the input factors equal zero in Table 1, the survival estimates are those for Program D Prime-Relocated (DRE).

The factor FIS in Table 1 is the fraction of the population who use the shelters (Categories A through Y) assigned in the shelter posture established for the program. For a single shelter category, FIS = 1 - FS - FE, where FS is the fraction of those persons assigned to the category who are "stay-puts" (i.e., persons who have not started to go to shelter) and FE is the fraction assigned to the category who are caught in the open by a detonation. When FIS = 0 for the whole population, it means that the total population is indoors in residential buildings at random. In analyses of a program, the performance of a shelter posture is determined by the use made of the shelters. Therefore, the factor FIS is better suited for the simplified method than the FS and FE factors used in the POPDEF algorithm.

The value in the "difference" columns for each input factor is the result of subtracting the "estimate" for that factor from that for DRE (none). Thus, for FCR = 0, the difference in uninjured survival is 0.662 - 0.362 = 0.300 and in total survival 0.747 - 0.477 = 0.280. That these differences do not represent the increases in survival attributable solely to each of the input factors can be seen in Table 1 where the sum of the differences in uninjured survival (0.759) is larger than the estimated uninjured survival for the whole program (0.662). This is an indication of the complex interactions among the input factors and the activities they represent. The "differences" in Table 1 generally overstate the increases in survival attributable to the individual input factors. For example, the sum of the total-survival differences for FCR = 0 and FPF = 0 in Table 1 is 0.280 + 0.010 = 0.290. But, the calculated total-survival difference when both FCR and FPF are set equal to zero is found to be 0.285. The "differences" in Table 1, then, should be viewed as first-order approximations of the relative contributions of the input factors to the increase in survival.

In this light, the significance of Table 1 lies in the observation that four of the input factors — FCR, FIS, FPF, and FER — contribute about 98 percent of the total of all the differences, both for uninjured and for total survival. Therefore, it appears that a calculation method employing as variable terms the four key input factors —FCR, FIS, FPF, and FER — should yield estimates of performance sufficiently accurate for use in comparative evaluations of alternative program elements within Program D Prime. It must be noted that this finding may be specific to Program D Prime and

Attack B. An analysis of a different program or the same program under a different attack might lead to a different finding. However, the analytic technique may be applied to any combination of program and attack.

When evaluating a civil defense program, it is customary to compare its performance with that of some other program. For example, in evaluating the future Program D Prime (DRE), its performance has been compared with that of the current program, Current Capability Maintained (CCM).[2,3] But what this really means is that CCM would increase survival by some amount over the survival that could be expected without civil defense and DRE would increase survival by some other amount over the survival that could be expected without civil defense. The performance of DRE with respect to CCM is the difference between these two amounts. This view of the evaluation is inherent in the POPDEF/PAM method. When FPF is said to have a value of 0.65, it means that 65 percent of the population would achieve improved fallout posture as compared with none if FPF were equal to zero. Then, when it is estimated that 0.757 of the population would survive with DRE, it means that this constitutes some fraction of the population more than it would be if there were no civil defense. Therefore, there is a "no civil defense case" (CDO) inherent in the POPDEF methodology. It is the case when all inputs are set equal to zero: no one leaves the risk areas, no one goes to shelter, no one is rescued, and the like. This case is shown on the bottom line of Table 1. About 28 percent of the population survives in this artificial case, with 16 percent of the population uninjured. Program D Prime increases the surviving population by nearly 50 percent and increases the number of uninjured survivors even more.

The zero-base concept can be applied to analysis of the POPDEF input factors. For this analysis, six different postures of Program D Prime were selected:

- DPRO - Program D Prime with FCR = 0; i.e., none of the Risk population is relocated.

- DIP - Program D Prime without a directed relocation; i.e., with only spontaneous relocation from the Risk areas (FCR = 0.27[3]).

- DCO - Program D Prime with directed relocation but without any Direction and Control capability (FCR = 0.57).

- o DCC - Program D Prime with directed relocation but with Direction and Control capability as in the current capability (FCR = 0.69).

- o DRE - Program D Prime with directed relocation (FCR = 0.77[3]).

- o DRI - Program D Prime with FCR = 1.0; i.e., all of the Risk population is relocated.

PAM estimates were made for all POPDEF input factors for each posture. POPDEF survival estimates were made for the complete posture and for FIS, FPF, and FER equal to zero as was described above for the sensitivity analysis. The results of these calculations are given in Appendix C.

Table 2 lists estimates of survival added by FPF for the six postures. These estimates were obtained by subtracting the values for FPF = 0 from the "total" values in Table C-2. The values of FPF were taken from Table C-3.

Table 2

INCREASE IN SURVIVAL - FPF
(Fractions of Population - Attack B)

Posture	FPF	Uninjured Survival Added	Total Survival Added
DPRO	0.46	0.0084	0.0054
DIP	0.58	0.0111	0.0063
DCD	0.32	0.0076	0.0039
DCC	0.50	0.0184	0.0073
DRE	0.65	0.0255	0.0098
DRI	0.77	0.297	0.0114

Then, by fitting linear regression lines to the FPF and survival-added data points, it is found:

$$U_f = 0.052\ \text{FPF} - 0.0114 \quad (R = 0.869) \qquad (1)$$

$$T_f = 0.017\ \text{FPF} - 0.0020 \quad (R = 0.946) \qquad (2)$$

Where:

U_f = added fraction of population surviving uninjured over the CDO case because of improved fallout posture.

T_f = total added fraction of population surviving over the CDO case because of improved fallout posture.

R = correlation coefficient.

In view of the high R values for Equations 1 and 2, it can be taken that the variation in survival added by improved fallout posture is linear with respect to FPF. However, it is noted that this finding is not critical with respect to the simplified method. If the relationship were not linear, the proper form could be found and used. In that case, the method would not be quite so simplified.

Similarly, Table 3 lists estimates of survival added by FER obtained by subtracting the values for FER = 0 from the "total" values in Table C-2. The values of FER were taken from Table C-3.

Table 3

INCREASE IN SURVIVAL - FER
(Fractions of Population - Attack B)

Posture	FER	Uninjured Survival Added	Total Survival Added
DPRO	0.23	0.0453	0.0262
DIP	0.44	0.0534	0.0271
DCD	0.12	0.0193	0.0102
DCC	0.49	0.0808	0.0427
DRE	0.67	0.110	0.0580
DRI	0.79	0.131	0.0684

When linear regression lines are fitted to the data points for FER and survival added, it is found:

$$U_e = 0.171 \text{ FER} - 0.0068 \quad (R = 0.982) \qquad (3)$$

$$T_e = 0.081 \text{ FER} - 0.0041 \quad (R = 0.978) \qquad (4)$$

Where:

U_e = added fraction of population surviving uninjured over the CDO case because of remedial movement after emerging from shelter.

T_e = total added fraction of population surviving over the CDO case because of remedial movement after emerging from shelter.

Again, the high values of R indicate that the variation in added survival with respect to FER can be taken to be linear.

In analyzing FIS, the survival added by shelter cannot be isolated directly by setting FIS = 0 because, by definition, this puts everyone in buildings at random and the effects of improved fallout posture and remedial movement, which are shelter-related activities, would still apply. To find the survival added by shelter, it is necessary to allow for the survival added by FPF and FER. Table 4 lists the estimates of survival added by FIS obtained by subtracting the sum of the values for FIS = 0 from Table C-2 and the "survival added" values for FPF and FER from Tables 2 and 3 from the "total" values in Table C-2. Values of FIS were taken from Table C-3.

Table 4

INCREASE IN SURVIVAL - FIS
(Fractions of Population - Attack B)

Posture	FIS	Uninjured Survival Added	Total Survival Added
DPRO	0.78	0.145	0.155
DIP	0.83	0.170	0.167
DCO	0.88	0.168	0.163
DCC	0.90	0.165	0.174
DRE	0.92	0.172	0.177
DRI	0.95	0.177	0.176

Once again, when linear regression lines are fitted to the data points for FIS and survival added, it is found:

$$U_s = 0.150 \text{ FIS} + 0.035 \quad (R = 0.836) \qquad (5)$$

$$T_s = 0.131 \text{ FIS} + 0.055 \quad (R = 0.908) \qquad (6)$$

The high values of R indicate, again, that the relationship in survival added with respect to FIS can be taken to be linear.

The survival added by relocation (FCR) is equal to the difference between the survival with no civil defense (CDO) and that for FIS = 0. Survival in the CDO case was found in a POPDEF computer calculation to be as shown in Table 1. Table 5 lists estimates of survival added related to FCR obtained by subtracting these values from the values for FIS = 0 in Table C-2. Values of FCR were taken from Table C-3.

Table 5

INCREASE IN SURVIVAL - FCR
(Fractions of Population - Attack B)

Posture	FCR	Uninjured Survival Added	Total Survival Added
DPRO	0	0.001	0.014
DIP	0.27	0.072	0.100
DCO	0.57	0.142	0.176
DCC	0.69	0.174	0.212
DRE	0.77	0.192	0.236
DRI	1.0	0.249	0.305

Then, when linear regression lines are fitted to the data points for FCR and survival added, it is found:

$$U_r = 0.247 \text{ FCR} + 0.0027 \qquad (R = 1.0) \qquad (7)$$

$$T_r = 0.286 \text{ FCR} + 0.016 \qquad (R = 0.999) \qquad (8)$$

These correlation factors are the best obtained in the four analyses and the relationship between FCR and survival added can again be taken to be linear.

Because the capability of Program D Prime can be represented by these four factors, the total survival for Program D Prime can be found in:

$$U_d = U_r + U_s + U_f + U_e + U_o \quad (9)$$

$$T_D = T_R + T_s + T_f + T_e + T_o \quad (10)$$

Where:

U_D = fraction of population surviving uninjured given Program D Prime.

T_D = total fraction of population surviving given Program D Prime.

U_o = fraction of population surviving uninjured given no civil defense (CDO).

T_o = total fraction of population surviving given no civil defense (CDO).

Then, substituting from Equations 1, 3, 5, and 7 in Equation 9 and Equations 2, 4, 6, and 8 in Equation 10 and combining the constants, Equations 9 and 10 become:

$$U_D = 0.247FCR + 0.150FIS + 0.052FPF + 0.171FER + 0.181 \quad (11)$$

$$T_D = 0.286FCR + 0.131FIS + 0.017FPF + 0.091FER + 0.341 \quad (12)$$

A number of assumptions are implicit in the above analysis. To test whether Equations 11 and 12 are an acceptable substitute for POPDEF for estimating performance in evaluating alternatives among the elements of Program D Prime, estimates using the equations are compared to POPDEF computer estimates for the six postures shown in Table 6.

Table 6

COMPARISON OF ESTIMATES

Posture	Uninjured Survival: Equation 11	Uninjured Survival: POPDEF	Total Survival: Equation 12	Total Survival: POPDEF
DPRO	0.378	0.362	0.481	0.477
DIP	0.478	0.468	0.577	0.576
DCO	0.491	0.499	0.641	0.634
DCC	0.596	0.605	0.709	0.712
DRE	0.658	0.662	0.754	0.757
DRI	0.746	0.749	0.836	0.837

The input estimates for PAM from which the POPDEF input factors and survival estimates used above were calculated were entered to two decimal places (in a maximum of two significant digits). Therefore, it appears from the correspondence seen in Table 6 that the estimates produced by this simplified method would be satisfactory for their intended purpose. It will be noted that the correspondence for total survival is somewhat better than that for uninjured survival. This is probably attributable to the better correlation coefficients for Equations 2 and 6 compared to those for Equations 1 and 5. It is noted that Equations 11 and 12 are specific to Program D Prime and Attack B. However, similar equations could be derived for other programs and other attacks by applying the technique demonstrated above.

Limitations on Method

It will be demonstrated in Section III that the simplified method is useful for analyzing the performance of a program for which POPDEF/PAM survival estimates have been made and for evaluating alternatives among the program elements. It will also be seen that the method has limitations. The more significant of these limitations are discussed in the following paragraphs.

The POPDEF input factors listed in Table 1 are not complete, as can be seen in Figure A-2; they comprise largely the "operational" factors; i.e., those that represent program elements that involve actions in the emergency situation. Consequently, the method cannot accommodate a change in the sheltering element that involves a different kind of shelter or a different policy for shelter assignment. Neither can it accommodate such program elements as shelter stocks or ventilation kits. Analyses involving such program elements will require the use of the POPDEF model.

The Program Analysis Model (PAM) results of Reference 3 that supplied the data from which the simplified method was developed did not treat crisis relocation planning or shelter use planning specifically. Therefore, analyses or evaluations involving these program elements require further work in applying the simplified method.

This simplified method is a surrogate only for POPDEF calculations; it does not change the need for input factor calculations in PAM. However, because only the changes in PAM inputs need be accounted for, the recalculations of the required PAM outputs are significantly less difficult and time-consuming than original PAM calculations are. But, even with these limitations, this simplified method is more convenient than the POPDEF model for comparison of program elements. It requires the handling of only a small fraction of the data required for POPDEF and it obviates the use of the

FEMA computer. Once again, however, it must be emphasized that the simplified method is not a substitute for POPDEF in estimating the performance of total systems. Also, POPDEF, as presently configured, has its own limitations, the most important of which are discussed in the remainder of this section as background for the analysis of Section III.

POPDEF - Population Distribution

The population input data now being used in POPDEF is the 1975 population as defined for Risk, Host, and Neither areas by TR-82.[5] However, in the work under Contract No. DCPA01-78-C-0293 (Rapid Enhancement), which examined the Risk-to-Host allocations in current Crisis Relocation Planning, it was found that the resident populations in Neither areas differed substantially from that defined by TR-82. The two distributions are given in Table 7 for the resident populations and for the relocated populations for Program D Prime-Relocated (DRE); i.e., Program D Prime after directed relocation (FCR = 0.77).

Table 7

POPULATION DISTRIBUTIONS
(Fractions of Total)

	Resident Population		Relocated Population	
Area	TR-82	CR Plans	TR-82	CR Plans
Risk	0.651	0.641	0.150	0.147
Host	0.336	0.290	0.837	0.784
Neither	0.013	0.069	0.013	0.069

These differences, especially with respect to the Host and Neither areas, point to the likelihood of systematic error in the results of POPDEF calculations. The size of this error is difficult to estimate accurately. However, a manual calculation of survival for DRE using the "CR Plans" distribution was made by applying the survival ratio for the several classes of shelter calculated previously for the TR-82 distribution and assuming that the people in the Neither areas outside the TR-82 Green areas would be subject to the Host area attack environment and would receive civil defense as in the Current Capability Maintained (CCM) program. The resulting survival estimates are shown and compared to those for the TR-82 distribution in Table 8.

Table 8

SURVIVAL ESTIMATES - DRE
(Fractions of Total Population)

Area	Total Survival TR-82	CR Plans
Risk	0.045	0.044
Host	0.705	0.664
Neither	0.006	0.044
Total	0.756	0.752

The difference between the total estimates is relatively small although it amounts to over 1 million survivors (projected 1980 population). However, the difference in Host-area estimates is about 6 percent and in the Neither-area estimates, a factor of seven. These differences would likely be significant in evaluations of partial programs, especially those that are geographically limited.

It appears, then, that distributions of the population (Risk, Host, and Neither) derived from realistic allocations for the program being evaluated should be used in POPDEF calculations. This will likely require the use of hosting ratios at the county level instead of at the state level as at present. These county-level ratios are available from the work under Contract No. DCPA01-78-C-0293.

POPDEF - Attack Environment Matrices

In the POPDEF model, the attack environment is introduced in the form of matrices that contain summary fractions of the population that are subjected to pairs of stated limits of blast overpressure (psi) and residual radiation (ERD). Three such matrices are used, one each for the populations in Risk, Host, and Neither areas. Each of these matrices is produced by the TENOS model for the calculated geographic distribution of the population given a value for FCR, the fraction of the Risk population relocated. A set of attack environment matrices is calculated for each distribution of the population. Within the set, the matrices for the Risk and Neither areas do not change: that for the Neither areas because neither the numbers of people nor their locations change; that for the Risk areas because it is taken that relocatees leave in equal proportions from all parts of all Risk areas.

However, the geographic distribution of the population in Host areas differs with the value of FCR because of the variation in the hosting ratios. In theory, then, there should be a Host-area attack environment matrix for each different value of FCR. In the applications of POPDEF in Reference 3 and in this present study, only two Host-area matrices have been used for each attack: one for FCR = 0.20 and one for FCR = 0.80. That for FCR = 0.20 has been used for all cases in which the estimated value of FCR was less than 0.50; that for FCR = 0.80 has been used for all cases with FCR greater than 0.50.

To obtain an indication of the possible error in POPDEF estimates because of the use of only two attack environment matrices, POPDEF calculations were made for DRE and CCM using the two matrices. The results are shown in Table 9.

Table 9

SURVIVAL VS. ATTACK ENVIRONMENT MATRIX
(Fractions of Total Population)

		Survival Fraction		
Program	Area	FCR = 0.20	FCR = 0.80	Difference
	Risk	0.045	0.045	-
DRE	Host	0.714	0.705	0.009
	Neither	0.006	0.006	
	Total	0.765	0.756	0.009
	Risk	0.096	0.096	-
CCM	Host	0.301	0.289	0.012
	Neither	0.004	0.004	
	Total	0.401	0.389	0.012

If the change in survival estimate for the Host area is proportional to FCR, which seems likely, the previous estimates of survival for CCM and DRE are probably accurate. However, for cases in which the FCR value is near the middle of the range, e.g., the Paper Plans Only (PPO) program in Reference 3 or DCO referred to earlier in this section, the error could be on the order of 0.004 of the total population. Errors of this magnitude are not especially significant in estimates of survival for total programs, but they can be significant in analyses of the performance of individual program elements.

It seems that a more accurate representation of the attack environment might be obtained with little added difficulty by proportionately merging the two matrices produced for the Host area in the present practice. If the two matrices were calculated for FCR = 0.20 and FCR = 0.80, each element in the combined matrix could be found from Equation 13:

$$X_{ij} = \frac{0.80 - FCR}{0.60} (X'_{ij}) + \frac{FCR - 0.20}{0.60} (X''_{ij}) \qquad (13)$$

Where:

X_{ij} = value of element in row i of column j in combined matrix.

X'_{ij} = value of element in row i of column j in matrix calculated for FCR = 020.

X''_{ij} = value of element in row i of column j in matrix calculated for FCR = 80.

FCR = fraction of Risk population relocating.

Then, the POPDEF inputs for the attack environment would consist of one matrix for Risk areas, two matrices for Host areas, and one matrix for Neither areas, with the Host matrices evaluated for the specified FCR by means of Equation 13.

POPDEF - Shelter Assignment (FA)

Quality of protection is introduced into POPDEF by the Shelter Assignment factor FA. In FA, fractions of the population (Risk, Host, and Neither) are assigned to the several categories of public shelter, to home basements, to special shelters, and to residential structures at random. The basic assignment is made in the TENOS model in which unit-area populations are compared to the availability of NSS shelter in the unit areas as recorded in the NSS file. The findings of this comparison are then modified to account for changes that would result from pertinent elements of the program being evaluated.

However, the NSS file is incomplete because it does not contain NSS shelter data for counties in which the shelter survey has not been completed. It is inaccurate because it does not contain the latest data from all Host counties in which the survey has been completed. Also, for below-ground spaces, the shelter capacity is at an increased allowance of square feet per occupant to compensate for lack of sufficient ventilation. As a consequence, the process of constructing the shelter allocation for a POPDEF calculation entails a number of "adjustments" that are described in Reference 3. The application of these adjustments not only requires substantial time and effort but also reduces the level of confidence in the accuracy of the resulting shelter allocation. The difficulty is exacerbated when a number of cases involving different values of FCR must be calculated, as in the analyses described later on in this section and in Section III.

The difficulty largely could be eliminated by modifying the TENOS allocation (1) to apply to the availability of NSS shelter as projected to the completion of the survey in all counties and (2) to permit changes in the rate of assignment to the several classes of shelter because of projected program accomplishments. If this were done, it would at least assure consistency for comparative evaluation of alternatives that would cause changes in the shelter assignments.

PAM - Fraction Relocated (FCR)

In PAM, the calculation of FCR is static; i.e., the estimate produced is for a composite of all Risk areas as of the end of the planned relocation period. This presents two problems. First, the movement is dynamic; i.e., the fraction of the Risk population who have relocated increases with the passing of time until all who intend to relocate have done so. Second, the Risk areas are not a composite; they include large and small places that have different movement rates. As a result, PAM cannot provide answers to the questions: How would program performance change if the attack were to come X hours after the Presidential Declaration? and How would program performance change if planning priority were given to large metropolitan Risk areas vs. small, isolated Risk areas?

In addition, PAM treats spontaneous evacuation (and direct relocation) as though all of those persons relocating would move to the Host areas allocated to them. This might not necessarily be so; many of them could well go to Neither areas, to Host areas in which they were not expected or planned for, or even to other Risk areas. Maladaptive behavior can be minimized through emergency public information. If such behavior occurs, it can be corrected by Direction and Control activities to relieve the resulting imbalances. Therefore, to evaluate these program elements requires that the model be able to account for this random movement of relocatees.

Correction of these two factors of PAM would require some extension of the final part of the FCR system tree.[2] In addition, accounting for the random movement of some relocatees would require modification in the way in which POPDEF calculates the distribution of people to Host and Neither areas after relocation. It might also require some modification of the attack environment matrix for Neither areas.

PAM - System Damage

At a number of places in the PAM calculations in previous work,[3] it was necessary to apply judgment as to the survival of elements of the civil defense system. For example, in estimating the capability of Direction and Control to inform the public, it was judged that survival of the D & C staff and facilities would be at least equal to that of people in shelters. The validity of this assumption cannot be tested in the absence of data on survival of EOCs. For another example, in the calculation of system ability to report on the situation (DZD), the best estimate of the effectiveness of wardens was judged to be 0.6 in Risk areas and 1.0 in Host areas to account for injury. But from the POPDEF output it is found that 5 percent of the survivors in public shelters in Risk areas and 2.5 percent of the survivors in Host areas suffer blast injury. Therefore, it appears that the effectiveness estimate for wardens might better have been 0.95 for Risk areas and 0.98 for Host areas. Other notable discrepancies occur in the estimated survival of communications.

The judgmental element in the PAM output could be reduced if an assessment of damage to elements of the system were available for the attack(s) used in the evaluation.

PAM - Medical Care

The POPDEF model assumes minimum medical care in its damage functions and PAM does not now provide for a medical care element of the civil defense system. Whenever damage functions that can account for higher levels of medical care capability can be introduced to POPDEF, it will be necessary to expand PAM to permit estimating of medical care capability.

III. ANALYSIS OF PROGRAM ELEMENTS

This section demonstrates techniques for (1) analyzing a defined civil defense program for which PAM and POPDEF calculations have been made to ascertain the contribution of individual program elements to overall program performance, (2) deriving cost/effectiveness ratios for individual program elements, and (3) evaluating alternatives within the program. Several program elements are discussed in terms of their performance. All discussions are in the context of Program D Prime as subjected to Attack B.[2,3]

Program Elements

For this analysis the following definitions of the elements of Program D Prime were derived from Reference 4:

- Direction & Control (DC): Staffing and procurement of facilities and communications for direction, control, and coordination of emergency operations and as a source of emergency public information.
- Citizen Training (CCT): Activities to educate the public to assist their own protection and to ameliorate the effects of an attack including preparing and publishing educational materials.
- Emergency Broadcasting (EBS): Procurement and installation of protection for broadcasting facilities and their staffs and emergency power and fuel to help assure operating capability after an attack.
- Radiological Monitors (RDM): Recruiting and training of Radiological Officers and Monitors so as to provide the capability to measure radiation intensities and advise as to their significance, given instruments.
- Radiological Instruments (RDI): Procurement and distribution of instruments for measuring the intensity of and exposure to radiation after a nuclear attack.
- Wardens (WRD): Recruiting and training of wardens (shelter management officers and shelter managers) to direct and control emergency operations within shelters and in the vicinity of shelters by forces drawn from shelter

occupants and to assist in such other civil defense measures as educating the public, warning, movement to shelter, and remedial measures after leaving the shelters.

- Operations Plans (PB): Preparation and publishing of plans for organization, direction, control, coordination, and information flow for conducting emergency operations and informing the public in the emergency.
- Organization Exercises (PI): Preparation and conduct of exercises in which the emergency organization functions under simulated emergency conditions for training and for evaluating emergency plans and operating procedures.
- Crisis Relocation Planning (CRP): Preparation and publishing of plans for relocation of persons from Risk to Host areas, for reception and care of the relocatees, for transporting key workers to and from their duty stations, and for continued supply of essential resources.
- Sheltering (SHL): Survey of available shelter and planning for its use; preparation and publishing of plans for assigning populations to shelters, movement to shelters, conduct of operations in and near shelters, and remedial measures after leaving the shelters; and preparation of plans for supplying additional shelters by modifying existing structures or constructing expedient shelters.
- Shelter Stocks (SK): Procurement and distribution of supplies — notably containers for drinking water — to prevent shelterees from being forced out of shelters prematurely because of dehydration.
- Ventilation (SJ): Procurement and installation of equipment to improve the ventilation of shelters to prevent shelterees from being forced out of shelters prematurely by excessive heat and humidity.

Analysis of Program Element Performance

The objective of this analysis is to ascertain the contribution of each of the program elements defined above to the performance of Program D Prime in the relocated mode (DRE). For purposes of this study, "performance" is taken to mean the increase in fractions of the preattack population who would survive, uninjured and total, given Program D Prime over the fractions of the preattack population who would survive given the Current Capability Maintained (CCM). The performance of each program element is measured by the increase in survival produced by its capability, given Program D Prime, over that produced by its current capability.

In this analysis, the simplified method developed in Section II will be used. This method employs four of the POPDEF input factors (FCR, FIS, FPF, and FER). Each of the program elements contributes to one or more of these input factors. PAM calculations were made for each of the program elements giving the PAM inputs for each factor the values appropriate to CCM. The considerations applied in making these PAM estimates are discussed in Appendix C. The results are given in Table 10. Four program elements—CRP, SHL, SK, and SJ—have been omitted from Table 10 because the contribution of these elements cannot be calculated directly by the simplified method.

Table 10

FACTORS FOR ESTIMATING ELEMENT PERFORMANCE
(Element Given CCM Status)

Program Element	FCR	FIS	FPF	FER
DC	0.69	0.90	0.50	0.49
CCT	0.76	0.90	0.64	0.63
EBS	0.77	0.92	0.63	0.66
RDM	0.77	0.92	0.31	0.66
RDI	0.77	0.92	0.61	0.67
WRD	0.72	0.91	0.57	0.44
PB	0.72	0.91	0.61	0.63
PI	0.75	0.91	0.65	0.64
(DRE)	0.77	0.915	0.65	0.67
(CCM)	0.16	0.47	0.04	0.03

The contribution of each program element in Table 10 with respect to each of the four input factors can be calculated directly from the terms in Equations 11 and 12 (Section II). For example, to find the contribution of DC through the FCR factor to uninjured survival:

(from Table 10)	FCR (DRE) =	0.77		
	FCR (DC) =	<u>0.69</u>		
(from Equation 11)		0.08 x 0.247	=	0.020

When similar calculations have been made for all elements in Table 10 and for all four factors, the results are as shown in Table 11. The subtotals for FCR and FIS are used below.

Table 11

CONTRIBUTIONS OF SURVIVAL
(Fractions of Total Population)

Program Element	FCR	FIS	FPF	FER	Total
Uninjured					
DC	0.020	0.003	0.008	0.031	0.062
CCT	0.002	0.003	-	0.008	0.013
EBS	-	-	0.001	0.002	0.003
RDM	-	-	0.018	0.002	0.020
RDI	-	-	0.002	-	0.002
WRD	0.012	0.002	0.004	0.039	0.058
PB	0.012	0.002	0.002	0.008	0.023
PI	0.005	0.002	-	0.005	0.012
(Subtotal)	(0.051)	(0.012)			
Total					
DC	0.023	0.003	0.003	0.013	0.042
CCT	0.003	0.003	-	0.003	0.009
EBS	-	-	-	0.001	0.001
RDM	-	-	0.006	0.001	0.007
RDI	-	-	0.001	-	0.001
WRD	0.014	0.001	0.001	0.016	0.032
PB	0.014	0.001	0.001	0.003	0.019
PI	0.006	0.001	-	0.002	0.009
(Subtotal)	(0.060)	(0.009)			

The contribution of Crisis Relocation Planning (CRP) to program performance cannot be calculated directly by the simplified method. However, in the analysis of performance related to FCR in Section II it was seen that survival for FIS = 0 was directly proportional to FCR. And because FIS = 0 means that everyone is in buildings at random this applies equally to CCM and to DRE. Therefore, the total increase in survival related to FCR is equal to the difference in FCR values for DRE and CCM shown in Table 10 multiplied by the coefficient of the first term in Equations 11 and 12. To find the contribution of CRP it is necessary to subtract the contributions of the other elements that contribute performance related to FCR. Then, for CRP:

	Uninjured	Total
Total (0.77 - 0.16) x 0.247	0.151	
(0.77 - 0.16) x 0.286		0.174
Subtotal (Table 11)	0.051	0.060
CRP	0.100	0.114

The contribution of Sheltering (SHL) cannot be calculated directly for two reasons. First, the sheltering element of CCM is sufficiently different from that of DRE that Equations 11 and 12 do not apply to the CCM element. Second, the simplified method does not account for changes in SK and SJ because they are subsumed in FIS. These require POPDEF calculations to find their contributions. The survival added by CCM shelter was also calculated. Then, the total contribution of all program elements for the FIS term is found by taking the *difference* between survival added by shelters in CCM (calculated manually) and that in DRE (calculated from Equations 5 and 6). The SHL contribution is found by subtracting from this remainder, the sum of the FIS contributions of SK, SJ, and the subtotal of the elements listed in Table 11. Then, for SHL:

	Uninjured	Total
Total (DRE, Table 4)	0.172	0.177
CCM	(-) 0.060	(-) 0.059
SK	(-) 0.044	(-) 0.030
SJ	(-) 0.007	(-) 0.004
Subtotal (Table 11)	(-) 0.012	(-) 0.009
SHL	0.049	0.075

When the above values for CRP, SHL, SK, and SJ are added to Table 11, the contributions for all of the program elements are as shown in Table 12, in decreasing

Table 12

SURVIVAL ADDED BY PROGRAM D PRIME - DRE
(Fractions of Population - Attack B)

Program Element	FCR	FIS	FPF	FER	Total
Uninjured					
CRP	0.100				0.100
DC	0.020	0.003	0.008	0.031	0.062
WRD	0.012	0.002	0.004	0.040	0.058
SHL		0.049			0.049
SK		0.044			0.044
PB	0.012	0.002	0.002	0.007	0.023
RDM			0.018	0.002	0.020
CCT	0.002	0.003		0.008	0.013
PI	0.005	0.002		0.005	0.012
SJ		0.007			0.007
EBS			0.001	0.002	0.003
RDI			0.003		0.003
Total	0.151	0.112	0.036	0.095	0.394
Total					
CRP	0.114				0.114
SHL		0.075			0.075
DC	0.023	0.003	0.003	0.015	0.044
WRD	0.014	0.001	0.001	0.022	0.038
SK		0.030			0.030
PB	0.014	0.001	0.001	0.004	0.020
PI	0.006	0.001		0.003	0.010
CCT	0.003	0.003		0.003	0.009
RDM			0.005	0.001	0.006
SJ		0.004			0.004
EBS				0.001	0.001
RDI			0.001		0.001
Total	0.174	0.118	0.011	0.049	0.352

order of performance. It should be noted that the totals in Table 12 for survival added, both uninjured and total, are about one percent less than those calculated directly by POPDEF, which is a little better than predicted in the sensitivity analysis in Section II.

Performance Versus Cost

One objective of analyzing performance of a program is to obtain a basis for arriving at an arrangement of program elements that would achieve the most in performance for a given investment. Therefore, it is desirable to relate the estimated performance shown in Table 12 to program element costs. To provide a basis for comparison, this relationship is expressed in terms of the ratio of cost to performance and, for this, the conventional term is "cost per survivor added."

For this analysis, costs of program elements in Program D Prime have been taken from the summary given in Reference 4, page 6. The breakout of costs given in Reference 4 has been adjusted to fit the identification of program elements used here, as shown in Table 13. The cost Radiological Defense was apportioned between monitors and instruments as indicated on page 19 of Reference 4. Costs of Shelter Survey and Nuclear Protection Planning were partitioned as indicated in Reference 3.

The survival shown in Table 12 in terms of fractions of the total population for each program element was converted to "survivors added" in Table 14 using a total population of 230.1 million. This estimate was derived from "average annual cost" and "average annual cost per survivor" as given in page 6 of Reference 4, and was taken to be consistent with the program cost estimates. The cost-per-survivor-added (CSA) estimates in Table 14 were obtained by dividing the number of survivors added into the program cost for each element.

Ventilation Kit Options

In the evaluation of Program D Prime reported in Reference 3, the shelter assignment (FA) for the Host and Neither areas in the relocated mode was based on the following assignment and ventilation kit policies:

> Ventilation kits will be installed in NSS basement shelters (A, B/C) and in upgraded shelters (XU) and all assignments to these shelters will be based on the allowance of 10 square feet per shelter space.

Table 13

ESTIMATED COST - PROGRAM D PRIME-DRE
(FY 1981 Dollars)

Program Element	Summary Item	Item Cost (dollars)	Element Cost (millions of dollars)*
DC	Emergency Operating Centers	$437.2	
	Communications & Warning	106.5	$ 543.7
CCT	EPI & Crisis citizen training		79.4
EBS	Broadcast station protection		163.2
RDM	Radiological defense		50.3
RDI	Radiological defense		361.0
WRD	Shelter management		23.4
PB	0.3 nuclear protection plan		97.9
PI	D & C exercising		98.8
CRP	0.5 shelter survey	62.9	
	0.5 nuclear protection plan	163.2	226.1
SK	Shelter marking	13.5	
	Shelter stocks	293.5	307.0
SJ	Ventilation kits		136.3
SHL	0.5 shelter survey	62.9	
	0.2 nuclear protection plan	65.3	
	Plans for crisis development	92.8	221.0
Total			$2,308.1

*Including prorated share of program management and research and development costs.

This differs from earlier D Prime policies for shelter assignment and ventilation kit placement in the host and Neither areas which are as follows:

Ventilation kits will be installed in upgraded shelters (XU) and assignments will be based on the allowance of 10 square feet per shelter space in upgraded shelters and, depending on the climate, allowances of greater than 10 square feet in NSS basement shelters.

This analysis is addressed to examining the difference in performance of systems designed in accordance with these alternative policies. It examines two cases, which for convenience in reference are designated as Policy A and Policy B:

- o Policy A - shelters allocated in accordance with policy and ventilation kits actually installed.
- o Policy B - shelters allocated in accordance with policy and ventilation kits not installed.

Table 14

COST PER SURVIVOR ADDED - DRE
(FY 1981 Dollars - Attack B)

Program Element	Element Cost (millions of dollars)	Minimized Survival Added (millions)	Minimized Cost per SA (dollars)	Total Survival Added (millions)	Total Cost per SA (dollars)
WRD	$ 23.4	13.3	$ 2	8.7	$ 3
CRP	226.1	23.0	10	26.2	9
SHL	221.0	11.3	20	17.3	13
PB	97.9	5.3	18	4.6	21
RDM	50.3	4.6	11	1.4	36
CCT	79.4	3.0	26	2.1	38
SK	307.0	10.1	30	6.9	44
PI	98.8	2.8	36	2.3	43
DC	543.7	14.3	38	10.1	54
SJ	136.3	1.6	85	0.9	150
EBS	163.2	0.7	240	0.2	710
RDI	361.0	0.7	520	0.2	1,570
Total	$2,308.1	90.7	25	81.0	29

Case 1: Kits Installed

The shelter assignment according to the Policy A is shown in Table H-5 of Reference 3. The shelter assignment according to Policy B was developed in accordance with the method described in Appendix H of Reference 3. The assignments for the Risk areas are the same for the two policies. The Neither areas are not affected by relocation, so the shelter assignment using Policy B is the same as that given in Tables H-1 and H-2 of Reference 3, except that XU is substituted for "at random." For the Host areas, the expansion factor is adjusted for FCR = 0.77 and for completion of the Host area survey: 1.02 x 1.4 = 1.43. Then, from Figure H-2, assignments of Host-area residents and total relocated Host-area population to NSS shelters are as follows:

Shelter Category	Fraction Assigned	Residents Assigned* (millions)	Total Persons Assigned* (millions)
A	0.024	1.709	4.256
B/C	0.093	6.618	16.493
E/F	0.030	2.135	5.319
G/H/I	0.085	6.049	15.072
	0.232	16.511	41.140

The remaining Host-area residents are assigned to home basements in proportion to the availability of home basements: (71,159 - 16.511) x 0.52 = 28.417 (millions). Then, the assignment to upgraded shelters is: 177.313 - (41.140 + 28.417) = 107.756 (millions).

The resulting shelter allocations for the two policies are compared in the following tabulation:

	Number of Persons Assigned (millions)			
	Policy A		Policy B	
Shelter Category	Host	Neither	Host	Neither
D	23.937	1.374	28.417	1.605
A	6.029	0.028	4.256	0.017
B/C	27.483	0.735	16.493	0.322
E/F	5.319	0.077	5.319	0.110
G/H/I	17.909	0.195	15.072	0.314
XU	96.635	0.344	107.756	0.385

*Based on 1975 population = 211.744 million.

Survival given Policy B can be estimated using survival rates found in the calculations for Program D Prime (with Policy A) when the system is subjected to Attack B:

Survivors (Policy A)	=	160.167 (millions)
Survivors (Policy B)	=	159.294
Difference	=	0.873

In other words, installing ventilation kits in NSS basement shelters in Host and Neither areas and assigning persons to those shelters at the allowance of 10 square feet per space would add nearly 1 million survivors above Policy B, given Attack B.

Case 2: Kits Not Installed

If the ventilation kits are not installed and operated, those in shelter spaces for which kits were planned might be forced to leave prematurely.

In the calculation of effects of Attack B on the complete D Prime system, the fractions of those persons actually in Host area shelters who survived to the ventilation event were found to be:

	Survival to Ventilation Event		
Shelter Category	Number in Shelter (millions)	Survivors at Ventilation Event (millions)	Survival Rate
A	5.727	5.046	0.88109
B/C	26.109	21.970	0.84147
XU	91.804	77.137	0.84024

These rates can be used to estimate the numbers of Host area survivors to the ventilation event in these shelters given Policy B:

	Survival to Ventilation Event	
Shelter Category	Policy A (millions)	Policy B (millions)
A	5.046	3.750
B/C	21.970	13.878
XU	77.137	90.541

Those who are not forced to leave shelter by insufficient ventilation would emerge at the end of the planned stay. Then the number of persons lost because ventilation kits were not installed would be proportionate to the difference between the survival rates for those leaving shelter (a) because of insufficient ventilation and (b) on emergence. These rates were found to be as follows (for host areas and Attack B):

Shelter Category	Survival Rate After Leaving Shelter		
	Ventilation	Emergence	Difference
A	0.95858	0.96671	0.00813
B/C	0.96512	0.97180	0.00668
XU	0.95119	0.95969	0.00850

The number of survivors lost because of failure to install ventilation kits would be the products of these differential rates and the number of survivors forced out by insufficient ventilation. For the Host area and Attack B, these losses would be:

Shelter Category	Survivors Lost Without Kits	
	Policy A (millions)	Policy B (millions)
A	0.039	—
B/C	0.147	—
XU	0.650	0.769
	0.836	0.769

It was found that losses in the Neither areas are not significant. Then,

	Policy A (millions)	Policy B (millions)
Survival with kits	160.167	159.294
Lost without kits	0.836	0.769
Survival without kits	159.331	158.525
Difference	0.806 million	

Therefore, it appears that over 90 percent of the additional survival achievable by Policy A over Policy B could be achieved even if the ventilation kits were not installed. As will be seen later on, this results from the more intensive use of the best shelters.

Effectiveness of Ventilation Kits

The effectiveness in terms of added survivors when ventilation kits are installed and operated and full advantage is taken of the reduction in space allowance to 10 square feet in below-ground NSS and upgraded shelters is estimated to be:

Survivors (Policy A with kits)	=	160.167 (millions)
Survivors (Policy B without kits)	=	158.525
Survivors added		1.642

In addition, it is to be noted that supplying ventilation kits and taking full advantage of the opportunity to reduce space allowances would have an additional, highly significant effect. Given Policy B, 108 million upgraded shelter spaces would be required in the Host and Neither areas. With Policy A, this requirement would be reduced to 97 million spaces, a reduction of 11 million spaces (about 10 percent).

Shelter Allocation in Host Areas

Attack B would subject about 65 percent of the total resident population to blast effects. Figure 1 shows the numbers of persons (1975 population) remaining in the Risk and Host areas after relocation who would receive given levels of overpressure. Distributions are given for two postures of Program D Prime: (1) in-place (DIP) which assumes only spontaneous relocation (FCR = 0.27) and (2) relocated (DRE) which assumes directed relocation (FCR = 0.77). In Figure 1 for DRE, 23 million persons in Risk areas and 18 million persons in Host areas would receive 5 psi overpressure or more.

In Figure 1, it can be seen that directed relocation would reduce the number of persons receiving 5 psi overpressure or more in Risk areas from 69 million to 23 million. At the same time, it would increase the number of persons receiving 5 psi overpressure or more in the Host areas from 11 million to 18 million. This emphasizes the desirability of allocating as many persons as feasible to the better shelters in Host areas as well as Risk areas as a hedge against attacks of the weight and distribution of Attack B.

Table 15 shows the performance of the several categories of shelter in Host areas, given posture DRE and Attack B. As might be expected, the strong shelters,

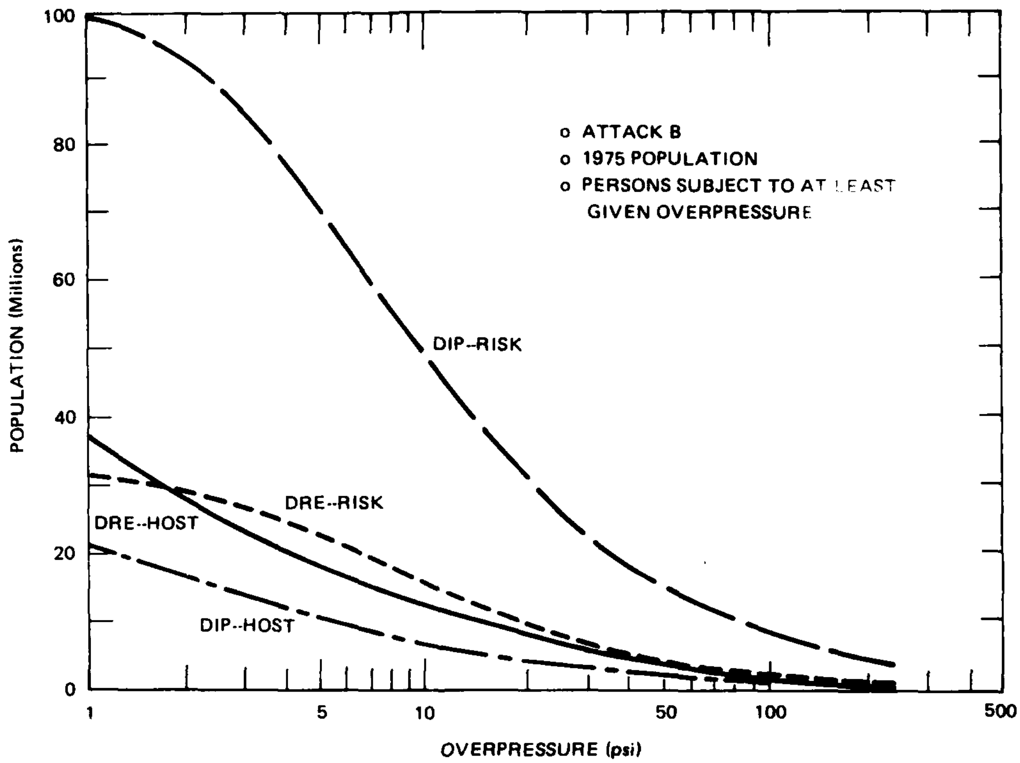

Figure 1. POPULATION DISTRIBUTION VERSUS OVERPRESSURE

A and B/C, perform best; i.e., they have the lowest total fatality rates. But several other significant findings can be drawn from Table 15. For example, over one-fifth of the fallout fatalities would occur among the 5 percent of the Host area population for whom shelter facilities were prepared but who chose not to use them; i.e., those who remain at random.

Table 15

PERFORMANCE OF SHELTER IN HOST AREAS - DRE
(1975 Population - Attack B)

Shelter Category	Population in Category (millions)	Blast Fatalities Millions	Blast Fatalities Rate*	Fallout Fatalities Millions	Fallout Fatalities Rate**	Total Rate*
Random	8.866	0.887	0.100	2.788	0.349	0.415
D	22.740	1.569	0.069	3.524	0.166	0.226
A	5.728	0.111	0.019	0.255	0.046	0.068
B/C	26.109	1.656	0.063	1.013	0.041	0.109
E/F	5.053	0.385	0.076	0.239	0.051	0.139
G/H/I	17.014	1.452	0.085	0.633	0.041	0.137
XU	91.805	8.718	0.095	4.025	0.048	0.143
In open	(4.371)	0.568	0.130	-		
Total	177.315	15.346		12.477		

* Fractions of population in category.

** Fractions of blast survivors.

It can be noted in Table 15 that, except for those persons at random and those persons sheltered in home basements (Category D), the fallout fatality rate varies relatively little although the rate protection factor (PF) for these shelters varies from 50(XU) to 5,000(A).[3] Most of those fatalities result from exposures received after the people leave the shelters. The substantially higher fallout fatality rates for those at random and in Category D result not only from lower rated PFs (10 and 25 respectively) but also from the lower effectiveness in achieving successful remedial movement from these categories compared to that for public shelters.

Upgraded Fallout Shelters in Neither Areas

In shelter-use planning, all categories of shelter are given their rated Protection Factor (PF) found in the survey, with the exception of the Upgraded category (XU), which is given the rated PF consistent with the planned upgrading. In other words, the rated PF of Category XU shelters will be as specified by the program. In analysis of Program D Prime, XU shelters have been assigned a rated PF of 50 and a rated MLOP of 5 psi. The purpose of the following analysis is to examine the performance of XU shelters in the Neither areas (the high-fallout, "green" areas outlined in TR-82).[5]

Figure 2 shows the distribution of free-field dose versus fractions of the Neither population who experience 5 psi overpressure or less in Attack B; i.e., survivors of those in shelters having a MLOP equal to 5 psi. The ordinate quantities are the fractions of those survivors subjected to the given free-field dose or more. Thus, 59 percent of the survivors would be subjected to a free-field ERD = 10,000r or more; 24 percent of the survivors would be subjected to 32,000r or more, and 10 percent of the survivors would be subjected to 86,000r, the highest level of free-field dose predicted in the "neither" areas for Attack B.

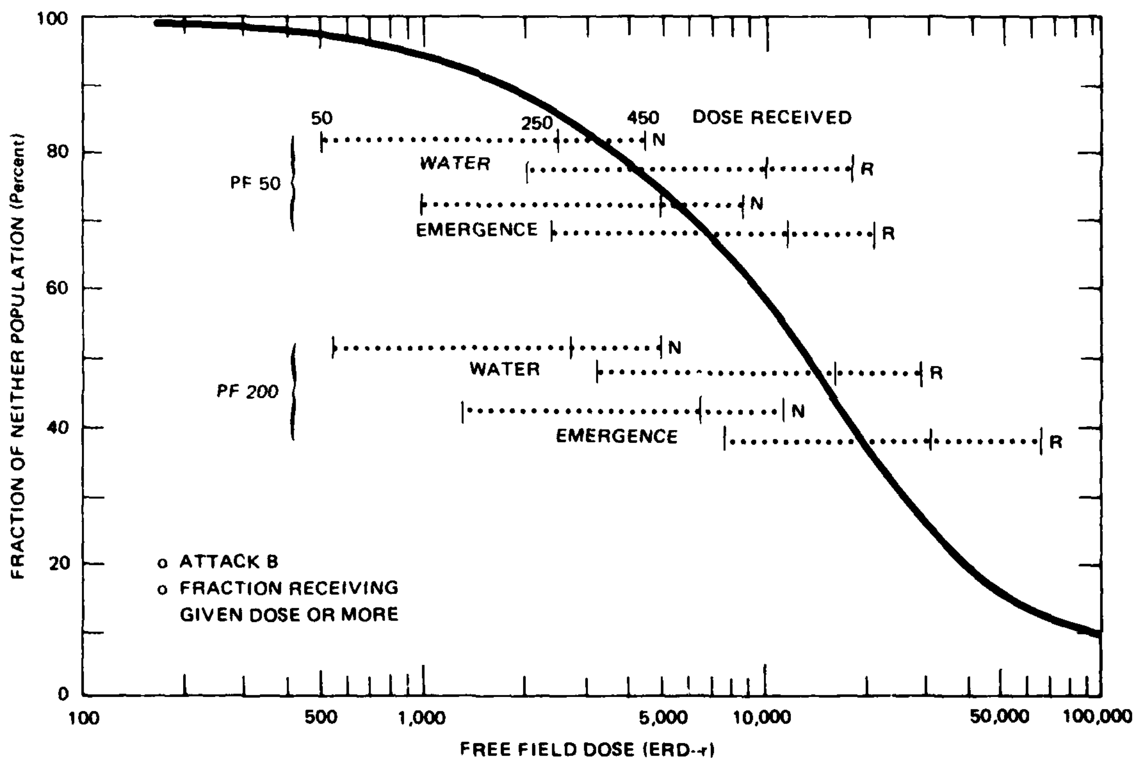

Figure 2. DISTRIBUTION OF RADIATION DOSE

The rated PF of a shelter applies only when the occupants remain in the shelter indefinitely.[1] When the shelter stay is of finite duration, the Effective Protection Factor (EPF) applying to the combination of the period in shelter and the period after leaving shelter is usually less than the rated PF. Table 16 gives the EPF for four scenarios: (1) being forced out of shelter by lack of drinking water (water) and (2) leaving the shelter at the end of the planned shelter stay (emergence), each with (3) remedial movement after leaving shelter (R) and with (4) no remedial movement (N). For each scenario, EPFs are given for rated PFs = 50 and 200.

Table 16

EQUIVALENT PROTECTION FACTORS

Scenario	PF = 50	PF = 200
Water (N)	10	11
Water (R)	41	65
Emergence (N)	20	26
Emergence (R)	48	127

Given these EPFs, it is possible to calculate the free-field dose that would produce a given level of received dose in the shelter occupants:

$$\text{Received dose} = \frac{\text{Free-field dose}}{\text{EPF}}$$

For this example, three levels of received dose are selected:

- o 50r, a desirable maximum level.
- o 250r, the sickness dose for those not injured by blast.
- o 450r, the fatal dose for those not injured by blast.

The implied free-field doses comparable to those levels of received dose are given in Table 17 for the scenarios and shelters listed in Table 16.

Table 17

IMPLIED FREE-FIELD DOSE - ERD

Rated PF	Scenario	50r	250r	450r
50	Water (N)	500	2,500	4,500
50	Water (R)	2,050	10,250	18,450
50	Emergence (N)	1,000	5,000	9,000
50	Emergence (R)	2,400	12,000	21,600
200	Water (N)	550	2,750	4,950
200	Water (R)	3,250	16,250	29,250
200	Emergence (N)	1,300	6,500	11,700
200	Emergence (R)	6,350	31,750	57,150

These implied free-field doses are located in Figure 2 by the marks on the labeled horizontal lines. Then, for example, for 50 PF - Water (N), it can be seen that 85 percent of the survivors in XU shelters would receive doses of 250r or more and 75 percent of the survivors would receive doses of 450r or more. This means that, of those persons who survived the blast effects uninjured in XU shelters with a PF of 50 and were forced out by lack of water without remedial movement, 75 percent would die from radiation and 10 percent (85-75) would suffer nonfatal radiation sickness. Only 15 percent would survive uninjured. The fractions of those persons surviving blast effects uninjured and who are not subsequently injured or killed by radiation are shown in Table 18 for the shelters and scenarios listed in Table 16.

Table 18

RADIATION INJURY AND FATALITY IN XU SHELTERS
(Fraction of Blast Uninjured)

Rated PF	Scenario	Uninjured (percent)	Injured (percent)	Killed (percent)
50	Water (N)	14%	15%	77%
50	Water (R)	42	18	40
50	Emergence (N)	25	13	62
50	Emergence (R)	44	19	37
200	Water (N)	15	10	75
200	Water (R)	56	18	26
200	Emergence (N)	31	14	55
200	Emergence (R)	75	14	11

In a previous evaluation of Program D Prime-Relocated (DRE),[3] the fraction of the population achieving successful remedial movement after being forced out of public shelters by lack of water (FWR) in the Neither areas was found to be 0.64, and that after emergence (FER) was found to be 0.74. When the values in Table 18 are combined in these proportions, the performance of XU shelters in the Neither areas with respect to those uninjured by blast is estimated to be as shown in Table 19.

Table 19

PERFORMANCE OF UPGRADED SHELTERS
(Neither Areas - DRE)

Rated PF	Event	Uninjured (percent)	Injured (percent)	Killed (percent)	Uninjured/ Injured
50	Water	30%	17%	53%	1.8
50	Emergence	39	17	44	2.3
200	Water	41	15	44	2.7
200	Emergence	64	14	22	4.6

To be complete, the analysis must also treat those persons injured by blast effects because of the difference in radiation injury and fatality levels for those uninjured and injured by blast effects. When this is done and the details on blast uninjured and injured are combined, the resulting estimates are unchanged from those given in Tables 18 and 19 because, in this case, those persons injured by blast were only 5 percent of the survivors of the detonation event.

Then, it can be seen in Table 18 that it is important to achieve a capability for remedial movement from XU shelters, no matter what else is done to them. Given this capability, it can be seen that both supplying water containers and increasing the protection factor can achieve substantial increases in survival and in the ratio of uninjured to injured survivors.

It might not be feasible to upgrade shelters to increase the PF to 200. However, Expedient Shelters (XE) have a rated PF of 200 and this could be an option. Analyzing the performance of other shelter categories (D, E/F, and G/H/I) would likely indicate performance similar to or worse than that of XU shelters; the option of substituting Category XF for them could also be considered.

Risk Area Community Shelter Planning

In Program D Prime, emphasis is placed on Crisis Relocation Planning (CRP) plus preparedness for emergency operations in the relocated mode. In-place protection is viewed as "an essential option, if time and circumstances preclude crisis evacuation,"[4] although in a number of program areas—e.g., shelter upgrading or shelter stocking—preparedness for in-place protection in the Risk areas is clearly subordinate to preparedness for crisis relocation. However, in the early years of the program, relocation capability would be limited and, even if crisis relocation were attempted, the population remaining in the Risk areas would be large. In that event, in-place protection in the Risk areas would be a requirement rather than an option.

To obtain an indication of the performance of Community Shelter Planning (CSP) in the Risk areas, two sets of POPDEF survival estimates were made for the Current Capability Maintained and for Levels of Operating Capability as follows:

- Level 1 (LOC 1): The ability to inform the public of planned destinations and routes for those relocating plus the ability to control and expedite the evacuation of persons in their own automobiles.
- Level 2 (LOC 2): LOC 1 plus the ability to relocate those requiring transportation, the ability to receive and care for those relocating, and the ability to inform the population in the Host areas, after relocation of the fallout shelter to be used.
- Level 3 (LOC 3): LOC 2 plus the ability to produce, in a crisis, needed improvised fallout shelter in Host areas and all-effects shelter for key workers in Risk areas plus the ability to transport key workers to and from their work places.
- Level 4 (LOC 4): LOC 3 plus the ability to direct emergency operations from protected ECOs and to inform the public over protected EBS stations, the ability to plan for shelter operations and to measure and interpret radiation intensities, the ability to relocate organizations, and the ability to exercise emergency organizations.
- Final: Program D Prime complete (DRE).

In one set of calculations, shelter assignments and use in the Risk areas were as in the current capability. In the second set, Risk-area shelter assignments and use were as in DRE. In both sets, preparedness for other than shelter in the Risk areas was in CCM through LOC 3 and as in DRE in LOC 4. The results are shown in Table 20.

Table 20

PERFORMANCE OF RISK AREA CSP
(Fractions of Total Population - Attack B)

Case	FCR	Risk CSP = CCM	Risk CSP = DRE	Survival Added
CCM	.16	0.401	0.467	0.066
LOC 1	.23	0.424	0.484	0.060
LOC 2	.38	0.484	0.533	0.049
LOC 3	.39	0.513	0.563	0.050
LOC 4	.77	0.702	0.718	0.016
DRE	.77	—	0.756	—

It can be seen that, for values of FCR less than 0.50, CSPs in the Risk areas could add survival in amounts from 0.05 to 0.066 of the total population (10 million to 15 million added survivors) and that, through LOC 2, Risk CSPs perform better than the next higher level of relocated operating capability.

Table 21 recasts the elements of added survival in terms of the schedule for Program D Prime. Predictions of the value of FCR versus program year were obtained by applying the scheduled expenditures to the estimated contributions of program elements to total survival added by relocation in Table 12. Estimates of "survival added" are in proportion to FCR.

Table 21

PERFORMANCE OF CSP VS. D PRIME PROGRAM YEAR
(Fractions of Total Population - Attack B)

Program Year	FCR	Survival Added by Risk CSP
1	0.19	0.064
2	0.25	0.059
3	0.30	0.055
4	0.45	0.043
5	0.57	0.033
6	0.70	0.023
7	0.77	—

It can be seen that the potential performance of risk area CSPs is substantial even in the sixth year of the program.

Emergency Broadcast Stations

The cost per survivor added for the Emergency Broadcast Station (EBS) element of Program D Prime can be seen in Table 14 to be relatively very high. This was unexpected because the EBS system is necessary for the emergency public information activities of Direction and Control (DC) and this affects all operations after the attack. Therefore, the original PAM calculations for DRE and CCM were examined for clues as to this poor performance.

The pertinent calculations appear as follows:

		Risk	Host	Neither
DRE	IE'	0.90	0.95	0.95
	K_4	0.95	0.95	0.95
	IE	0.86	0.90	0.90
CCM	IE'	0.95	0.95	0.95
	K_4	0.45	0.95	0.95
	IE	0.43	0.90	0.90

It appears that the estimates of the coverage of the population (IE') would be relatively unchanged by Program D Prime although the program proposes to add 2,000 additional stations to the 600 now in the system. In addition, the estimated survival rate (K_4) would be doubled in the Risk areas but would remain unchanged in Host and Neither areas. These comparisons seem to suggest that estimates of coverage and survival should receive critical review, especially those for the current capability. In this regard, it is well to note that "coverage" has an operational significance; i.e., it is related to the ability of an EOC to talk to the public in the area for which it has operational responsibility. Thus EBS stations that provide coverage for EOCs in the current capability might not provide satisfactory coverage for the EOCs that would exist at completion of Program D Prime.

Radiological Instruments

The performance of the radiological instrument (RDI) program element as given in Table 12 is relatively low and the cost per survivor added in Table 14 is relatively high. These results were unexpected because, traditionally, radiological instruments have been viewed as an essential element of any civil defense program.

The relatively low performance of RDI appears to result from the estimates of instrument availability for the Current Capability Maintained (CCM) and the estimated accomplishment in Program D Prime. In the PAM calculations for FPF,[3] it was estimated that, in CCM, 55 percent of public shelters in all areas would have radiological instruments available. It was estimated that Program D Prime would add instruments for 40 percent of the Host and Neither populations. This is equivalent to adding instrument capability for 21 percent of the total population. Much of this increased potential for adding survival is offset by the capability of shelter leaders to place the occupants in improved fallout posture without radiation instruments, given advice from D & C (the best estimate of this capability is 65 percent in public shelters).[3]

The relatively high cost per survivor added seems to result both from the low level of performance and from a possible overstatement of the requirement. If, as is noted above, Program D Prime is intended to supply instruments for 40 percent of Host and Neither area populations, this means a requirement to serve some 68 million spaces. Then, 7 million additional sets of instruments would be required at the rate of 1 set per 9 spaces.

It appears, then, that critical reviews of the PAM calculations involving radiation instruments with respect both to coverage and requirements and to the relative effectiveness of operations with and without their use should be worthwhile.

Program Element Package Analyses

The analyses of program element performance and performance versus cost presented above are valuable for understanding the relative value of the individual elements in achieving a stated objective, which in this case is the reduction in injury and fatalities. However, unless a program is to be deployed all at once out of one appropriation, it must be divided into parts and the deployment of the parts scheduled over a number of appropriations. Each of these parts of the program consists of one or more program elements and, to be most effective, the grouping must be logical because some program elements are prerequisites to others and some can be effective only in combination with others.

Reference 3 presented an analysis of performance and of performance versus cost of groups of elements of Program D Prime. In that analysis, the groups were termed "packages" and that term is used here. In Reference 3, the performance of the packages was estimated by means of POPDEF calculations. In this present analysis, package performance has been estimated from the performance estimates for individual program elements calculated by means of the simplified method described in Section II and given in Table 12. Package costs have been derived from the program element costs given in Table 13.

For this analysis the following program packages have been selected:

A. Paper plans: Preparation of plans for relocating the Risk area population to designated Host areas and for reception and care in the Host areas, plus development of a capability to inform and guide the public when relocation is directed.

B. Relocation effectiveness: Preparation of detailed plans for conducting a crisis relocation, plus development of a capability for the direction and control of relocation operations.

C. Sheltering and warning: Preparation of plans for shelter use, for production of additional shelter in a crisis, and for movement to shelter; improvement of the capability to warn the public; informing the public as to what they can and should do for their own protection; and preparation for informing the public specifically as to what they should do when moving to and occupying shelters.

D. Attack operations: Preparations for managing, directing, and controlling operations in the event of attack, including development of the capability to measure and interpret radiation intensity and dose.

E. Shelter endurance: Preparations for improving the environment within the shelters and the availability of essentials such as water, so as to obviate leaving the shelters before the end of the planned occupancy.

Costs of these packages were taken from Table 13, but some adjustments were required because the available cost estimates were not in sufficient detail. Estimated costs, following the pattern in Reference 3, were allocated as follows and as shown in Table 22.

A. Paper plans: From CRP, Shelter Survey 0.5 and Nuclear Protection Planning 0.5; from CCT, EPI and Crisis Citizen Training 0.25; and from EBS, Broadcast Station Protection 0.25.

B. Relocation effectiveness: From PB, Nuclear Protection Planning 0.3; from DC, Emergency Operating Centers 0.25 and Communications and Warning 0.5; from PI, D & C Exercising, 1.0.

C. Sheltering and warning: From SHL, Shelter Survey 0.5, Nuclear Protection Planning 0.2, and Plans for Crisis Production of Shelter 1.0; from DC Communications and Warning 0.5; from CCT, Crisis Citizen Training 0.75; and from EBS, Broadcast Station Protection 0.75.

D. Attack operations: From WRD, Shelter Management 1.0; from DC, Emergency Operating Centers 0.75; and from RDM and RDI, Radiological Defense 1.0.

E. Shelter endurance: From SK, Shelter Marking 1.0 and Shelter Stocks 1.0; and from SJ, Ventilation Kits 1.0.

Table 22

ESTIMATED COSTS - PROGRAM PACKAGES
(Millions of Dollars)

Summary Item	A Plans	B Relocation	C Shelter	D Operations	E Endurance
Shelter survey	$ 62.9		$ 62.9		
NCP planning	163.2	$ 97.9	65.3		
Shelter production plans			92.8		
Shelter mark & stock					$443.3
Shelter management				$23.4	
Warning			53.3		
EOC & communication		162.5		327.9	
D & C exercising		93.8			
RADEF				411.3	
CCT/EBS	60.6		182.0		
Total	$286.7	$354.2	$456.3	$762.6	$443.3

Program D Prime has been proposed as an alternative to the Current Capability Maintained (CCM) program which also contains investments in all of the packages except E, shelter endurance. To obtain a valid comparison of cost and performance between Program D Prime and CCM, it is necessary to adjust the gross package costs shown in Table 22 to account for the projected costs of the CCM program. This has been done in Table 23, which also shows the cumulative costs as succeeding packages are added. These cumulative costs are compared later on to the cumulative estimates of performance of the packages.

Performance of Package A was estimated in a separate POPDEF calculation because the PAM model is not yet in sufficient detail to enable isolation of performance of plans only. The remaining performance of Shelter Survey (in Table 12) was ascribed in Package C. The remaining performance of NCP Planning was ascribed to Package B.

Table 23

NET COSTS OF PROGRAM D PRIME PACKAGES
(Millions of Dollars)

Package	Gross Cost	CCM Allocations	Net Cost*	Cumulative Cost*
(CCM)		$(640)		$ 640
A	$ 286.7	120	$ 170	810
B	359.2	220	140	950
C	456.3	60	400	1,350
D	762.6	240	520	1,870
E	443.3	-	440	2,310
Total	$2,308.1	$640	$1,670	

*Rounded.

Performance of Packages C and E was taken from the FIS column. Performance of Package D was taken to be the sum of FPF and FER columns. Wherever the estimates in Table 12 did not correspond exactly with the breakout of costs in Table 22, they were partitioned in proportion to the dollar amounts. The resulting distributions of performance are shown in Table 24.

To demonstrate the method, the packages are treated here as sequential increments of a proposed program. A convenient way in which to compare their performance among themselves and with CCM is to graph cumulative performance against cumulative cost. For this, it is necessary to calculate total survival by adding the estimates of added survival from Table 24 to the estimates for CCM. This has been done and the results shown in Table 25 which also shows the ratio of uninjured to injured survivors.

Table 24

PERFORMANCE OF PROGRAM D PRIME PACKAGES
(Survival Added Over CCM)
(Fractions of Total Population)

Summary Item	A Plans	B Relocation	C Shelter	D Operations	E Endurance	Total
Uninjured survival						
Shelter survey	0.016		0.026			0.042
NCP planning	0.042	0.042	0.016	0.009		0.109
Shelter production plan			0.021			0.021
Shelter mark & stock					0.051	0.051
Shelter management		0.012	0.002	0.044		0.058
Warning			0.002	0.004		0.006
EOC & communications		0.018	0.003	0.035		0.056
D & C exercising		0.005	0.002	0.005		0.012
RADEF				0.023		0.023
CCT/EBS	0.001	0.001	0.003	0.011		0.016
Total	0.059	0.078	0.075	0.131	0.051	0.394
Total survival						
Shelter survey	0.020		0.033			0.053
NCP planning	0.052	0.044	0.023	0.005		0.124
Shelter production plan			0.032			0.032
Shelter mark & stock					0.034	0.034
Shelter management		0.014	0.001	0.023		0.038
Warning			0.002	0.002		0.004
EOC & communications		0.021	0.003	0.016		0.040
D & C exercising		0.006	0.001	0.003		0.010
RADEF				0.007		0.007
CCT/EBS	0.001	0.002	0.003	0.004		0.010
Total	0.073	0.087	0.098	0.060	0.034	0.352

Table 25

CUMULATIVE PERFORMANCE OF PROGRAM D PRIME PACKAGES
(Fractions of Total Population)

Packages	Uninjured	Total	Uninjured/Injured
(CCM)	0.264	0.401	1.9
A	0.323	0.475	2.1
A,B	0.401	0.562	2.5
A,B,C	0.476	0.660	2.6
A,B,C,D	0.607	0.720	5.4
A,B,C,D,E	0.658	0.754	6.9

These survival estimates have been plotted on the ordinates of Figure 3 against the cumulative cost estimates from Table 23 on the abscissa. The significance of Figure 3 is found in the slope of the graphs because the greater the slope, the greater the cost/effectiveness of the package. However, it must be noted again that the packages do not represent a logical program schedule and, therefore, Figure 3 is best viewed as demonstrative rather than substantive.

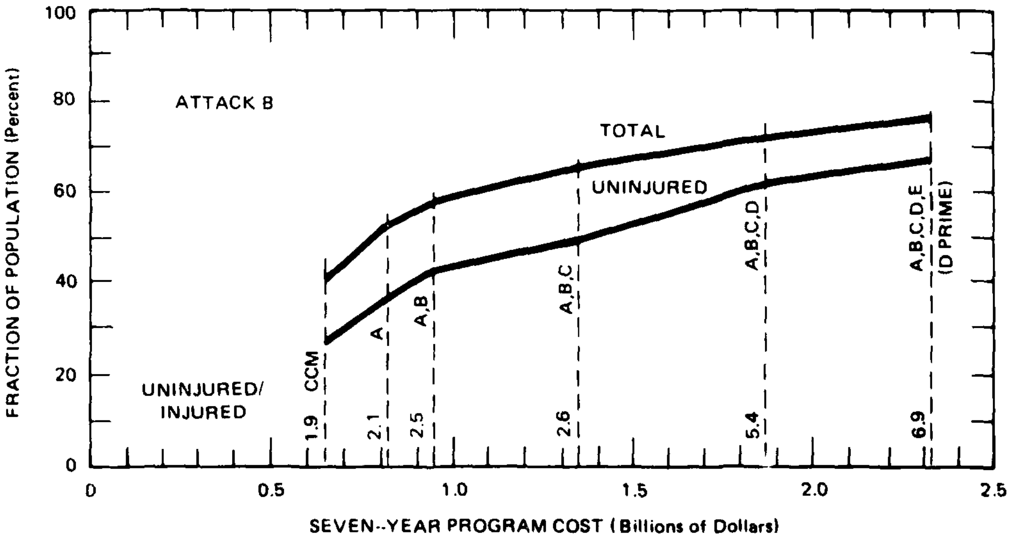

Figure 3. PERFORMANCE OF PROGRAM D PRIME PACKAGES

Another comparison that can be drawn is among the estimates of cost/effectiveness, i.e., the estimates of cost per survivor added for the several packages. These ratios have been calculated by the same method used above for calculating the cost per survivor added ratios for the individual program elements shown in Table 14. The results are shown in Table 26. It can be seen that the estimates of cost per survival added confirm the observation that the slope of the lines in Figure 3 is an indication of the cost/effectiveness ratio except for Package C and total survival added. However, in Table 23 it is seen that the allocation of CCM to Package C is substantially smaller in proportion than those for the other packages, except for Package E, where gross cost is net cost. This accounts for the higher cost/effectiveness ratio for Package C than is predicted by Figure 3.

Table 26

COST PER SURVIVOR ADDED - PROGRAM D PRIME PACKAGES - ATTACK B

		Uninjured		Total	
Package	Package Cost* (millions)	Survival Added (millions)	Cost* per SA	Survival Added (millions)	Cost* per SA
A	$286.7	13.6	$21	17.0	$17
B	359.2	17.9	20	20.0	18
C	456.3	17.3	26	22.5	20
D	762.6	30.1	25	13.8	55
E	433.3	11.7	38	7.8	57

*FY 1981 dollars.

The above analysis is a demonstration of an application of the assessment methodology so as to maximize the expected performance of a civil defense program in the course of a program deployment over a period of years. Or rather, it would be if it were taken that the packages were to be deployed in the order in which they were added. But this is not necessarily the optimum scheduling. For example, it can be seen in Table 24 that a substantial increase in the effectiveness of crisis relocation can be obtained when other program elements are deployed concurrently with NCP Planning and Shelter Survey.

This demonstration of the method suffered from a lack of correlation between the estimates of program accomplishments used in the original PAM calculations and the necessary allocations of program cost. For an analysis of this kind, there should be a one-to-one correlation between the estimates of program accomplishment entered into the PAM estimating process for program elements and the allocation of program cost to program elements. This does not mean that program cost estimates should necessarily be in proportion to estimated accomplishments. But any program accomplishment for which credit is taken in the PAM calculations should have an identifiable cost in the program cost estimate. A tableau of the general form of Figure 6 of Reference 1 should prove useful in providing the detail in the cost estimates needed for analysis involving cost and performance of program elements, whether individually or in packages.

IV. CONCLUSIONS AND RECOMMENDATIONS

Discussion

The main thrust of this study was the extension of the POPDEF/PAM methodology to estimating of the performance of program elements, individually and in combinations. This was a prerequisite to the analysis of a defined program to ascertain the contributions of its elements. A new methodology was developed and demonstrated specifically for Program D Prime and Attack B in Section II. This new methodology can be applied to any program and any attack for which POPDEF/PAM calculations have been made. However, the equations (similar to Equations 11 and 12, Section II) will be specific to the combination of program and attack.

The new methodology was applied to analysis of Program D Prime in the Relocated mode (DRE) when subjected to Attack B. This demonstration is discussed in Section III. Two analyses were made: one to find the contributions of the individual elements of Program D Prime to its performance and one to find the contributions of packages of elements similar to those examined in Reference 3. Estimates were made of the increases in survival, uninjured and total, attributable to each individual program element and each package of elements and of the associated cost per survivor added.

These analyses were appropriate for a demonstration of the method, but they were limited to the relocated mode of Program D Prime. However, directed relocation is held to be an option to protection in place, to be exercised if it appears feasible. Therefore, complete information as to the relative performance of program elements would require similar analyses of Program D Prime in the In-Place mode (DIP). This could be done using Equations 11 and 12 as in Section II, but the values of FCR, FIS, FPF, and FER for DIP are different from those for DRE.

In the estimates of survival added and cost per survivor added listed in Tables 12 and 14, the performance and cost effectiveness of the Emergency Broadcasting (EBS) and Radiological Instrument (RDI) elements appear quite poor when compared with the others. An examination of the original PAM calculations indicates that some of the input estimates related to these elements may not accurately reflect either the current capability or the projected capability or both. It appears that critical review of these input estimates might prove worthwhile. In addition, it appears that the amount of projected procurement of radiological instruments may not be necessary to achieve the increase in capability estimated for the PAM calculation. A critical review of the rationale for this program element may also prove worthwhile.

Several changes in Program D Prime or in policies related to its elements were considered. It was found that allocation of people to underground shelters (or their equivalent) at the reduced space allowance consistent with installation of ventilation kits would yield increased survival even if the kits were not installed. Program D Prime might be modified to extend the ventilation kit policy to the Risk areas.

An analysis of shelter performance in the Host areas under Attack B showed that it would be desirable to allocate people to the shelter categories having the greater blast resistance. The same finding would likely apply also to the Neither areas. This points to the desirabilty of addressing greater attention to finding Category A (mine, cave, and tunnel) shelters in Host and Neither areas as well as in Risk areas.

An analysis of the performance of Category XU (upgraded) shelters in the Neither areas (the green areas in TR-82)[5] indicates that substantially improved performance could be achieved in these areas if persons assigned to Category XU shelter could be given a rated PF of 200 rather than 50. It might not be feasible to increase the rated PF of XU shelters to 200 but it might be feasible to provide Category XE (expedient) shelters for these people. The same considerations would apply for people assigned to home basements and to Category E/F and G/H/I shelters. Also, it is noted that, even if the Neither areas are expanded to fit an actual Risk to Host relocation allocation, the green areas would remain within the expanded Neither areas.

An analysis of the performance of shelter in the Risk areas showed that, in the early segments of deployment of Program D Prime when relocation capability would be small, substantial increases in survival could be achieved if the Risk area shelter plans (CSP) were available. This indicates the desirability of increased effort on Risk-area CSPs in the early years of Program D Prime deployment.

In the cost-effectiveness analysis, it was found that the warden (shelter management) program element added survival at the least cost of all the elements. This follows from the assumption that the management capability could be achieved through training a cadre of shelter manager instructors (SM/I) and of shelter managers (SM) who would then serve as unpaid volunteers, plus preparation for training the remainder of the SM requirement in a crisis. This contrasts with the radiological monitor (RDM) program element which provides for full-time, paid radiological officers (RDO). In view of the estimated increase in uninjured survival by a factor of three and in total survival by a factor of six by shelter managers as contrasted to radiological monitors, it does not seem logical to rely on unpaid volunteers to achieve the shelter manager capability. Therefore, it appears desirable to modify Program D Prime to include full-time, paid SMO/Is, at least to the extent projected for RDOs.

If the projected investment in radiological instruments or in emergency broadcasting was determined to be greater than that needed, the savings could be allocated to defray any additional costs to be incurred because of such modifications in the program as were discussed above without changing the overall cost of the program.

In the cost-effectiveness analyses, it was found that the available cost estimates were not in sufficient detail and in some respects did not correspond to the increases in capability entered into the PAM calculations. It appears logical to expect that, unless an increase in capability can be achieved without cost to the program, every increase in capability claimed in the PAM calculations should have an associated program cost. In addition, if cost-effectiveness analyses are to provide a valid basis for judgment as to relative desirability among program elements, either individually or in combinations, program element costs should be available in exactly the same detail as are performance estimates. In other words, the costs of the program elements should be available in the same form and detail as Table 12 except that the entries should be in dollars of program cost instead of increased survival in fractions of the population.

The new technical data published in 1979 were reviewed to ascertain their significance, if any, for the effectiveness assessment methodology. No new data were found that would require modification of the methodology at this time. However, work under way on methods for increasing the blast resistance and shielding capability of upgraded shelters should, in the near future, produce results that would lead to modification of the rated characteristics of upgraded shelters.

Conclusions

On the basis of the preceding discussion, the following conclusions appear to be in order:

1. The extension of the POPDEF/PAM methodology provides an effective procedure for estimating the contribution of program elements, individually or in combination, to the overall performance of a civil defense program for which POPDEF and PAM performance estimates have been made.

2. The estimates of performance of program elements produced by the POPDEF/PAM methodology can serve as an effective basis for cost-effectiveness analyses. However, the estimates of cost for such analyses need to be correlated with the estimates of program achievement in increasing capability.

3. Comparison of estimates of performance and cost-effectiveness for program elements can identify areas of the original PAM calculations that should be given critical review.

4. Analyses of data produced by POPDEF/PAM calculations are effective in providing bases for identifying desirable modifications in program design.

5. The population data base now available for POPDEF calculations does not reflect the actual allocation of Risk populations to Host areas.

6. The PAM model does not account for the dynamics of the relocation movement in the calculation of Fraction Relocated (FCR) and it does not account for any possible spontaneous relocation into Neither areas.

7. The attack environment matrices produced by the present method in use in POPDEF do not correlate to the values of FCR produced by PAM.

8. The present method of producing shelter assignments is based on incomp'ete data as to shelter availability and requires the application of judgmental "adjustments" to derive a projection of shelter assignments.

9. Estimates of survival of operating elements of the system when subjected to attack effects must be entered into the PAM calculations by judgment not based on an assessment of damage.

10. Damage functions that account for higher than "minimum" levels of medical care are not available for the POPDEF model. Extension of the PAM model to account for medical care capabilities cannot be implemented in the POPDEF model until these damage functions are obtained.

Recommendations

From the preceding discussion and conclusions, the following recommendations appear appropriate:

1. The POPDEF/PAM methodology as extended should be used in comparative analyses of program elements, individually or in combination.

2. Preparation of program cost estimates should be formalized and should produce program cost distributions that may be applied directly to program element performance estimates.

3. The population data base for POPDEF calculations should be revised to conform to the planned allocation of Risk populations to Host areas.

4. The PAM model should be extended to account for the dynamics of the relocation movement and for spontaneous relocation into Neither areas.

5. The method of producing attack environment matrices should be revised to produce matrices that accurately reflect the post-relocation distributions of the population in Risk, Host, and Neither areas for any value of FCR.

6. The shelter availability data base should contain the latest survey data and the method of producing shelter assignments should provide for (a) projecting shelter availability to completion of the survey and (b) introduction of factors reflecting program accomplishments.

7. An assessment of damage to the projected civil defense system should be made for each program evaluated by the POPDEF/PAM methodology and for each attack used in the evaluations.

8. Damage functions reflecting higher levels of medical care should be derived for use in POPDEF.

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Appendix A

SUMMARY OF POPDEF AND PAM MODELS

Appendix A

SUMMARY OF POPDEF AND PAM MODELS

This study is based on the POPDEF/PAM methodology for estimating the performance of civil defense programs. The methodology is described in Reference 1 (400 pages) and its use is demonstrated in Reference 2 (330 pages) of this appendix. The general nature of the two models is summarized here for the convenience of the reader who needs only background information about the methodology to which many references are made in this report.

Casualty Assessment Models

Estimates of system costs and effectiveness are needed in the process of developing policies and assessing the nature and extent of civil defense preparedness programs. A methodology has been developed for estimating the individual and combined contributions of various program elements to total system effectiveness, as measured by casualty reduction. The casualty assessment part of this methodology is called the Population Defense Model (POPDEF). Many of the input parameters to POPDEF are subject to uncertainty. Hence, the Monte Carlo version of the Population Defense Model was developed to allow the user to define probability distributions for each of these parameters. The Monte Carlo version (MCPOPDEF) samples from these distributions particular values that are then used in POPDEF to determine the resulting casualties. After a user-specified number of cycles are performed, means and standard deviations are calculated for each output quantity and these results printed out.

Since MCPOPDEF is essentially a routine that uses the POPDEF model repeatedly as it progresses through the specified number of cycles, both models have been implemented in a single computer program. When a single cycle is specified, the program operates as POPDEF. When multiple cycles are specified, the program operates as MCPOPDEF. Normally, MCPOPDEF runs consist of 100 cycles, although smaller and larger runs have been made to test the behavior of the statistical output. The POPDEF model has been tested against manual calculations using the same input values.

As noted above, the POPDEF model is described in detail in Reference 2. The basic structure of the POPDEF model and the application of MCPOPDEF are summarized below.

The POPDEF Model

POPDEF is an aggregated casualty assessment routine that draws on the more detailed DCPA computer program, TENOS. TENOS operates on unit areas defined by two minutes of latitude and longitude over the Continental United States. POPDEF operates on three regions — Risk, Host, and Neither — using data aggregated from the unit areas by the TENOS model. For each region, TENOS is used to determine the population of the region for a stipulated fraction of the resident population of the Risk region relocated to the Host region (FCR), the distribution of this population with respect to attack effects (overpressure and ERD), and the population assignment to shelter categories (FA).

The model accommodates ten shelter categories, three of which are reserved for those at random in residences (unassigned, stay-puts, etc.), those in home basements, and those in the open at time of detonation. Each category is defined by rated protection characteristics — MLOP, MCOP, and PF — that are intended to reflect random location and posture in the shelter areas and minimal medical care for the injured.

POPDEF employs a "defense scenario" to trace the changes in vulnerability of the population in each shelter category. A typical tableau for one shelter category is shown in Table A-1. Except for the "Inputs," this tableau can be printed out for each shelter category in each area (Risk, Host, and Neither). (The "B/C" category shelters are in the basements and subbasements of large buildings.) The events of the defense scenario are shown at the left. The first event is the Shelter Assignment; that is, the product of the CSP planning process that determines where the population is to be sheltered. For each shelter category, there is a "Stay" column and a "Move" column, each of which is subdivided into uninjured (SU, MU) and injured (SI, MI) components. The entries in the table are in millions of people. Also shown on the right are the inputs to the computation program that must be specified, together with example values of the input parameters. (See also Figure A-1.)

The model calculates the populations in each area after relocation and the number of people in each shelter category; hence, the residence populations of the

Table A-1

EXAMPLE TABLEAU FOR CATEGORY "B/C"
(Risk Area with 77% Relocation)

EVENT	STAY: SU	STAY: SI	MOVE: MU	MOVE: MI	INPUTS	
SHELTER ASSIGNMENT	9.291				FCR = 0.77;	FA = 0.293
WARNING	7.930				FS = 0.12;	FE = 0.03
PROTECTIVE POSTURE	8.176				ΔMLOP = 0.03	ΔMSOP = 0.03
DETONATION	(3.179)	(.959)			ΔPF = 0.75;	FPF = 0.05
A. NOT TRAPPED	3.092	.613			MLOP = 10 PSI;	MCOP = 7 PSI
B. TRAPPED	.087	.346			MTOP = 9.1 PSI;	FTU = 0.20
					FF = 500	
RESCUE	3.092	.613	(.065)	(.260)	FR = 0.75	
D + 3.8(R)			.009	.005	FRR = 0.02	
D + 3.8(N)			.056	.255		
FIRE	2.821	.546	(.269)	(.067)	FF = 0.11;	FFR = 0.02
D + .0(R)			.000	.000	FFSS = 1.0;	FFSM = 0.99
D + .0(N)			.269	.067	PSIF = 2 PSI	
WATER	.850	.000	(1.971)	(.546)	FW_1 = 0.50;	FW_2 = 1.0
D + 1.5(R)			.285	.011	PSIFW = 4 PSI;	PSIW = 2 PSI
D + 1.9(N)			1.686	.535	FWR_1 = 0.64;	FWR_2 = 0.02
VENTILATION	.000	.000	(.850)	(.000)		
D + 3.8(R)			.153	.000	FV = 1.0;	PSIV = 2 PSI
D + 6.9(N)			.696	.000		
EMERGENCE			(.000)	(.000)	FVR_1 = 0.82;	FVR_2 = 0.02
D + 7.0(R)			.000	.000		
D + 9.0(N)			.000	.000	PSIE = 2 PSI	FER_1 = 0.82
					FER_2 = 0.02	

	Line	Low	Best	High				
FCR	1	.58	.77	.87	Use RELOC Input		File	
		Risk	Host	Remainder				
Resident Population	2	137.462	71.159	2.753	Use AEM 9		Output DRE	

Shelter Assignments - FA	Line	1 (9)	2	3	4	5	6	7	8
Estimates Low, Area R	3	.204	.256	.054	.295	.043	.020		.130
	4								
Estimates Low, Area H	5	.109	.135	.034	.155	.030	.101	.436	
	6								
Estimates Low, Area N	7	.025	.499	.010	.267	.028	.071	.100	
	8								
Estimates Best, Area R	9	.204	.256	.054	.295	.043	.020		.130
	10								
Estimates Best, Area H	11		.135	.034	.155	.030	.101	.545	
	12								
Estimates Best, Area N	13		.499	.010	.267	.028	.071	.125	
	14								
Estimates High, Area R	15		.244	.080	.222	.030	.020		.217
	16	.187							
Estimates High, Area H	17			.061	.236	.020	.145	.538	
	18								
Estimates High, Area N	19			.029	.384		.100		
	20	.487							
[illegible] - SKIOP	21								

Shelter Class	Line	2	3	4	5	6	7	8	9
Freezing - FS, Risk Area	22	.17	.21	.21	.21	.21			.21
	23	.11	.12	.12	.12	.12			.12
	24	.05	.05	.05	.05	.05			.05
Freezing - FS, Host Area	25	.05	.05	.05	.05	.05	.05		
	26	.05	.05	.05	.05	.05	.05		
	27	.05	.05	.05	.05	.05	.05		
Freezing - FS, Neither Area	28	.05	.05	.05	.05	.05	.05		.05
	29	.05	.05	.05	.05	.05	.05		.05
	30	.05	.05	.05	.05	.05	.05		.05
Freezing - FE, Risk Area	31		.23	.23	.23	.23			.23
	32		.03	.03	.03	.03			.03
	33		.01	.01	.01	.01			.01
Freezing - FE, Host Area	34		.23	.23	.23	.23	.23		
	35		.03	.03	.03	.03	.03		
	36		.01	.01	.01	.01	.01		
Freezing - FE, Neither Area	37		.23	.23	.23	.23	.23		.23
	38		.03	.03	.03	.03	.03		.03
	39		.01	.01	.01	.01	.01		.01

Lethal, Shelter Class	Line	Low		Best	High	
Rural	40	3	4	5	6	7
[illegible]	41	5	7	10	13	20
[illegible]	42	20	40	50	70	200
[illegible]	43	7	8.5	10	13	25
[illegible]	44	4	6	8	9	10
[illegible]	45	3	4	5	6	7
[illegible]	46	3	4	5	6	7
[illegible]	47	35	40	55	70	100
9 X E	48	10	12.5	15	27.5	40
[illegible]	49	2	2.5	3	4	6

Figure A-1. COMPLETE DATA INPUT FOR MCPOPDEF* FOR PROGRAM D PRIME RELOCATED (Sheet 1 of 5)

Section	Item	Card	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8
Median Casualty overpressure - MCOP	Estimate		Low		Best	High				
	Shelter Class 1 Rond	50	2	2	2	2	2			
	2 D	51	4	4	4	5	10			
	3 A	52	15	30	35	50	150			
	4 B/C	53	5	6	7	8	10			
	5 E/F	54	2	2	2	2	2			
	6 G/H/I	55	2	2	2	2	2			
	7 XU	56	2	2	2	2	2			
	8 Y	57	20	30	65	60	85			
	9 XE	58	9	11.5	14	22	30			
	10 open	59	1	1.5	2	2	2			
Probability of Value of MLOP or MCOP	MLOP/MCOP		.15	.35	.35	.15				
	Shelter Class 1 Rond	60	.15	.35	.35	.15				
	2 D	61	.15	.35	.35	.15				
	3 A	62	.15	.36	.40	.20				
	4 B/C	63	.10	.45	.25	.20				
	5 E/F	64	.15	.35	.35	.15				
	6 G/H/I	65	.15	.35	.35	.15				
	7 XU	66	.15	.35	.35	.15				
	8 Y	67	.15	.35	.35	.15				
	9 XE	68	.15	.35	.35	.15				
	10 open	69	.20	.20	.40	.20				
FSECOND	Shelter Class		1	2	3	4	5	6	7	8
			9	10						
	Absolute Upper	70	1,000	1,000	1,000	1,000	1,000	10	1,000	1,000
	Bound - MLOP	71	1,000	1,000						
Number of Cycles		72	100							
Protection Factor - PF	Shelter Class		1	2	3	4	5	6	7	8
			9							
	Estimate Low	73	5	10	1,000	100	20	40	20	100
		74	100							
	Estimate Best	75	10	25	5,000	500	55	70	50	200
		76	200							
	Estimate High	77	15	50	10,000	1,000	90	120	100	300
		78	300							
Remote			PFN	PFM	PFR					
Protection Factor		79	5	5.45	50					
Fractional increase in MLOP - MLOP / Fractional increase in MCOP - MCOP	Area		Risk			Host			Neither	
	Estimate		Low	Best	High	Low	Best	High	Low	Best
	Area		Neither							
	Estimate		High							
Shelter Class	1 Rond ΔMLOP	80								
		81								
	1 Rond ΔMCOP	82								
		83								
	2 C ΔMLOP	84	0	.01	.01	.01	.05	.10	.01	.05
		85	.10							
	2 C ΔMCOP	86	.02	.04	.07	.09	.27	.52	.08	.27
		87	.52							
	3 ΔMLOP	88	0	.01	.02	.04	.07	.09	.03	.06
		89	.09							
	3 ΔMCOP	90	0	.01	.02	.04	.07	.09	.03	.06
		91	.09							
	4 E/F ΔMLOP	92	.01	.03	.07	.11	.23	.37	.09	.20
		93	.35							
	4 E/F ΔMCOP	94	.01	.03	.07	.11	.23	.37	.09	.20
		95	.35							

Figure A-1. COMPLETE DATA INPUT FOR MCPOPDEF* FOR PROGRAM D PRIME RELOCATED (Sheet 2 of 5)

Area / Estimate	Code	Low	Risk Best	Risk High	Host Low	Host Best	Host High	Neither Low	Neither Best
Area Estimate		Neither High							
Amount	[illegible]	0	.01	.02	.04		.09	.03	.06
	[illegible]	.09							
Cancel	[illegible]	.03	.08	.17	.37	.66	.93	.30	.56
	[illegible]	.83							
Amount	[illegible]	.01	.04	.14	.15	.40	.74	.12	.34
	[illegible]	.70							
Cancel	[illegible]	.02	.04	.08	.19	.33	.47	.15	.28
	[illegible]	.44							
Cancel	[illegible]	0	.01	.02	.04	.07	.09	.03	.06
	[illegible]	.09							
Amount	[illegible]	0	.01	.02	.04	.07	.09	.03	.06
	[illegible]	.09							
Amount	[illegible]								
Cancel	[illegible]								
Cancel	[illegible]								
Cancel	[illegible]								
Amount	[illegible]								
Cancel	[illegible]								
[illegible]		1	2	3	4	5	6	7	8
		9							
[illegible]	[illegible]	0	1	0	.75	1	1	.75	0
		0							
Estimate		Low	Best	High					
[illegible]	[illegible]	.01	.02	.06					
[illegible]	[illegible]	.01	.05	.15					
[illegible]	[illegible]	.09	.23	.34					
[illegible]	[illegible]	.61	.84	.99					
[illegible]	[illegible]	.09	.23	.54					
[illegible]	[illegible]	.53	.79	.98					
[illegible]		1	2	3	4	5	6	7	8
		9							
[illegible]	[illegible]	.06	.02	.12	.20	.01	.02	.02	.11
	[illegible]	.20							
Low	[illegible]	.90	.56	1	.59	.65	.90	.90	1
	[illegible]	1							
Best	[illegible]	.97	.74	1	.75	.81	.97	.97	1
	[illegible]	1							
High	[illegible]	1	.89	1	.90	.93	1	1	1
	[illegible]	1							
[illegible]	[illegible]	2							

Figure A-1. COMPLETE DATA INPUT FOR MCPOPDEF* FOR PROGRAM D PRIME RELOCATED (Sheet 3 of 5)

Fraction Relocated-RR Given Remed. Memories	OP Region		< PSIR		> PSIR	
	Shelt. Class		R/O	other	R/O	other
Area / Risk / Estimate	Low	137	.11	.44	0	0
	Best	138	.22	.64	[illegible]	.02
	High	139	.34	.83	.02	[illegible]
Area / Host / Estimate	Low	140	.11	.44	0	0
	Best	141	.22	.64	.01	.02
	High	142	.34	.83	.02	.04
Neither / Estimate	Low	143	.10	.42	0	0
	Best	144	.22	.64	.01	.02
	High	145	.34	.83	.02	[illegible]
PSIFF		146	2			

	Shelter Class		1	2	3	4	5	6	7	8
			9							
Fract. Forced Out by Fire · FR / Estimate	Low	147	0	.06	0	.03	.03	0	0	0
		148	0							
	Best	149	.03	.13	0	.11	.10	.03	.03	0
		150	0							
	High	151	.10	.23	0	.22	.21	.10	.11	0
		152	0							
Fract. Forced Out Service PSS / Estimate	Low	153	1	.97	1	.97	.97	.99	.99	1
		154	1							
	Best	155	1	.98	1	.99	.99	1	1	1
		156	1							
	High	157	1	.98	1	1	1	1	1	1
		158	1							
Fract. in Shelt. Service Fire	FFSS	159	1	1	1	1	1	1	1	1
		160	1							
PSIF		161	2							

Fract. Fire not & Fire Given Remed. Area	OP Region		< PSIF		> PSIF	
	Shelt. Class		R/O	other	R/O	other
Area / Risk / Estimate	Low	162	0	0	0	0
	Best	163	0	0	0	0
	High	164	.01	.04	.01	.04
Area / Host / Estimate	Low	165	0	0	0	0
	Best	166	0	0	0	0
	High	167	.01	.04	.01	.04
Neither / Estimate	Low	168	0	0	0	0
	Best	169	0	0	0	0
	High	170	.01	.04	.01	.04
PSIFW		171	4			

	Shelter Class		1	2	3	4	5	6	7	8
			9							
Fraction Forced Out by Loss of Water · PW / Area / Risk / Overpressure Region	< PSIFW	172	0	0	.50	.50	.50	.50	.50	0
		173	.50							
	> PSIFW	174	1	1	1	1	1	1	1	0
		175	1							
Area / Host / Overpressure Region	< PSIFW	176	0	0	0	0	0	0	0	0
		177	0							
	> PSIFW	178	1	1	1	1	1	1	1	0
		179	1							
Neither / Overpressure Region	< PSIFW	180	0	0	.50	.50	.50	.50	.50	0
		181	.50							
	> PSIFW	182	1	1	1	1	1	1	1	1
		183	1							
PSIW		184	2							

Figure A-1. COMPLETE DATA INPUT FOR MCPOPDEF* FOR PROGRAM D PRIME RELOCATED (Sheet 4 of 5)

Fract. Forc. out by Water Given Remed. Meas. - FWK					< PSIW		> PSIW	
OP Region					R/C	other	R/C	other
Shelt. Class								
Area	Risk	Estimate	Low	185	.11	.44	0	0
			Best	186	.22	.64	.01	.02
			High	187	.34	.83	.02	.04
	Host		Low	188	.11	.44	0	0
			Best	189	.22	.64	.01	.02
			High	190	.34	.83	.02	.04
	Neither		Low	191	.10	.42	0	0
			Best	192	.22	.64	.01	.02
			High	193	.34	.83	.02	.04

Fract. Forc. out by Ventilation - FV			1	2	3	4	5	6	7	8
Shelter Class			2							
Area	Risk	194	0	0	1	1	0	0	1	0
		195	0							
	Host	196	0	0	0	0	0	0	0	0
		197	0							
	Neither	198	0	0	1	1	0	0	1	0
		199	0							
PSIV		200	2							

Fract. Forc. out by Vent Given Remed. Meas. - FVK					< PSIV		> PSIV	
OP Region					R/C	other	R/C	other
Shelt. Class								
Area	Risk	Estimate	Low	201	1	.61	1	.01
			Best	202	1	.82	1	.02
			High	203	1	.93	1	.05
	Host		Low	204	1	.61	1	.01
			Best	205	1	.82	1	.02
			High	206	1	.93	1	.05
	Neither		Low	207	1	.50	1	.01
			Best	208	1	.74	1	.02
			High	209	1	.91	1	.05
FSIE				210	2			

Fraction Emerging Given Remed. Meas. - FEK				< PSIE		> PSIE	
OP Region				R/C	other	R/C	other
Shelt. Class							
Area	Risk	Low	211	.27	.61	0	.01
		Best	212	.50	.82	.01	.02
		High	213	.69	.93	.04	.05
	Host	Low	214	.27	.61	0	.01
		Best	215	.50	.82	.01	.02
		High	216	.69	.93	.04	.05
	Neither	Low	217	.14	.50	0	.01
		Best	218	.36	.74	.01	.02
		High	219	.59	.91	.04	.05

TA Area		Risk	Host	Neither	
Time of Arrival	220	1	5	5	
TRL Estimate		Low	Best	High	
Time of Rescue	221	48	90	120	
Time Forc. by Fire	222	1			
TW Remed. Meas.		TWR	TWN		
Nom. Log Time Water	223	36	45.6		
TV Remed. Meas.		TVR	TVN		
Nom. Log Time Vent.	224	91.?	165.6		
TE Remed. Meas.		TER	TEN		
Nom. Log Time Emerg.	225	168	216		
Time Remed. Meas. - TM	226	4			
ERC Category		ERCPMH	ERRFAIL	ERRCMC	ERRCMT
Med. Treat. Cost	227	450	375	250	200

Figure A-1. COMPLETE DATA INPUT FOR MCPOPDEF* FOR PROGRAM D PRIME RELOCATED (Sheet 5 of 5)

Risk, Host, and Neither areas are also inputs to the computation. FCR, the fraction of the Risk population that has relocated to the Host area prior to attack, thus defines the population in the Risk Area at the time of attack. FCR is taken here to be 77 percent. The value of FCR is calculated by means of the Program Analysis Model described later on. The fraction of the population assigned to shelter category B/C is FA, which is an output of the TENOS shelter assignment process at the unit area specified: FS, the fraction not moving to shelter, and FE, the fraction caught in the open enroute to shelter. The example values shown in Table A-1 are 0.12 for FS and 0.03 for FE. Thus, the assignment, 9.291 million, must be multiplied by 0.12 to determine that 1.115 million are stay-puts at the time of attack. The remainder, 8.176 million, move to shelter. Of these, 3 percent are caught enroute, leaving 7.930 million in shelter category B/C at the time of attack.

The Protective Posture event is now introduced into the scenario. This activity does not change the amount of population in shelter but it does change the vulnerability of this population to attack effects. The rated protection characteristics of the B/C shelter category (MLOP, MCOP, PF, and the casualty functions on which they are based) assume random location and posture (standing, sitting, or lying down). If, for example, shelter managers were to seat shelterees along the walls and around columns away from the center of ceiling spans, both fatalities and injuries would be reduced. This defense action is accounted for in the computation by means of the inputs MLOP and MCOP. Estimates of these parameters are obtained in two steps: first "technical" estimates are made of the fractional increase in MLOP and MCOP if everyone were in the protective posture. This potential increase is then multiplied by an estimate of the fraction of the shelter population (calculated in PAM) actually in the protective posture to obtain the net MLOP and MCOP. In the example, both MLOP and MCOP are assessed at 3 percent. This means that the survivors on the Detonation line will be assessed by entering the attack environment matrix with an MLOP of 10.3 psi rather than 10.0 psi and an MCOP of 7.2 psi rather than 7 psi. This procedure is satisfactory because the distribution of population with overpressure is uniform in the region of interest for large attacks.

Similarly, the rated PF of a shelter is based on random location and posture. If, after fallout arrival, a shelter monitor or manager is able to locate the safest place in the shelter area and group the occupants there, a substantial improvement in fallout protection can usually be achieved. In shelter category B/C, the "technical" estimate is 75 percent ($\Delta PF = 0.75$) if all shelter occupants assume the fallout protective posture. In POPDEF, the estimate of the fraction of the shelter population actually in the protective posture, FFP (obtained from PAM), is not multiplied by the potential ΔPF to obtain a net value. Rather, the survivors in shelter are divided into two groups, one at the rated PF and one at the augmented PF. Thus, in the example shown in Table A-1, 95 percent of the occupants would be assessed at a rated PF of 500 and 5 percent of the occupants would be assessed at a PF of 875.

The event, Medical Care, is shown at this point in the scenario because it is another defensive action that can alter the casualty outcome without changing the location of the population. It is shown in parentheses because it has not yet been operationalized in POPDEF. Casualty functions appropriate to levels of medical care are not available for the shelter categories used in POPDEF. Hence, all casualty assessments made by the model at its present stage of development are based on minimal medical care.

At the Detonation event, fatalities and injuries from direct effects are assessed. The details on surviving uninjured and injured are shown in parentheses in the Stay column. The sum of uninjured and injured is the total number of survivors in the location. The entries are obtained by entering an attack environment matrix, such as the one in Table A-2, using the modified MLOP and MCOP. This matrix, which is the aggregate result of applying the TENOS model to all Risk unit areas, shows the percentage of Risk population in areas experiencing less than the blast overpressure shown in the column heading and less than the equivalent residual dose (ERD) shown in the row heading. The bottom row of this matrix is used to assess detonation fatalities and injuries. The fraction of the population experiencing less than the MLOP is considered to survive in this shelter category. The fraction of the population experiencing less than the MCOP is considered to be uninjured survivors. Thus, interpolation between the 5-psi and 10-psi entries indicates that 40 percent of the risk population experiences overpressure of less than 7.2 psi and is classed as uninjured. Multiplying the 7.930 million in this shelter category by this factor yields the 3.129 million shown in the SU column.

The detonation survivors are then partitioned into those who are trapped in debris and those who are not. This is accomplished by associating with each location a median trapping overpressure (MTOP). Survivors experiencing less than the MTOP are not trapped. Further, a value is assigned to the fraction of the trapped who are

Table A-2

ATTACK ENVIRONMENT MATRIX FOR RISK AREA - ATTACK B

ERD	Percent of Population Experiencing Less Than Indicated ERD (r) and Blast Overpressure (psi)										
	2 psi	3 psi	5 psi	10 psi	15 psi	20 psi	25 psi	35 psi	50 psi	75 psi	100 psi
170	0%	1%	1%	2%	2%	2%	2%	3%	3%	3%	3%
260	1	1	2	3	3	3	3	3	3	3	3
430	1.	2	3	3	4	4	4	4	4	4	4
640	1	2	3	4	5	5	5	5	5	5	5
860	1	3	4	5	6	6	6	7	7	7	7
1,300	2	3	5	7	8	9	9	9	9	10	10
1,700	2	4	7	10	11	11	12	12	13	13	13
2,600	3	6	9	18	15	16	16	17	18	18	19
4,300	4	8	14	20	23	25	26	27	29	29	30
6,400	4	10	17	25	30	32	33	36	37	38	39
8,600	5	11	20	30	35	38	40	42	44	46	47
17,000	6	14	25	40	47	52	55	59	62	65	66
43,000	7	17	30	49	58	64	69	74	79	83	85
86,000	8	17	31	51	62	69	74	80	85	90	92
170,000	8	17	31	51	62	69	74	80	85	90	92

uninjured (FTU). This permits the trapped and not-trapped to be defined as uninjured and injured. The sum of trapped and not-trapped in each column must equal the survivors carried in parentheses on the Detonation line. This procedure is necessary so that the Rescue and Fire events can be assessed.

The rescue activity operates on the trapped fraction. Hence, the population percentages in the Stay columns consist of those not trapped plus the survivors of those caught in the open enroute to this shelter category. The latter are estimated as part of the "in open" shelter category and assumed to continue to the assigned shelter. The survivors shown in the Move columns in parentheses are the fraction of the trapped who are rescued, which is determined by the input, FR, which in this example is taken to be 75 percent. The rescued survivors are divided into those afforded remedial radiological measures (R) and those who are not (N) by FRR, taken as 2 percent in this example. POPDEF has the capability to accept differing estimates of the effectiveness of remedial movement as functions of (a) time after attack and (b) location of survivors with respect to physical damage. Since all rescue occurs in the damaged area, only one value of FRR is necessary.

The Fire event operates on the Stay fractions shown on the Rescue line. The inputs to the calculations are FF, the fraction of survivors forced out of shelter by the fire threat; FFR, the fraction of those afforded remedial radiological measures; FFSS, the fraction of those not forced out who survive; and FFSM, the fraction of those forced out who survive. The input, PSIF, taken to be 2 psi in Table A-1, defines the overpressure level above which the fire situation exists.

The calculations for the Fire event illustrate some of the complexities incorporated into POPDEF. Consider the SI column in Table A-1. The 0.613 million persons who are injured survivors after the Rescue event are all within the 2-psi region. Hence, the 0.546 million persons remaining after the Fire event represent 89 percent of the original 0.613 million persons, and the 0.067 million persons in the MI column are the 11 percent of the injured forced out of shelter by fire (FF = 0.11). (The latter survivors are also reduced by FFSM, but the survival rate is so high that the difference does not appear in this rounding.) However, the 0.269 million persons in the MU column represent only about 10 percent of the 11.53 percent uninjured in the SU column after the Rescue event. This comes about because about one-third of the uninjured survivors are in the overpressure regions less than 2 psi according to the attack environment matrix underlying this example calculation. Hence, the FF of 11 percent can be assessed only on the approximately two-thirds of survivors that are in the fire area. Thus, 2.821 million persons remain uninjured in this shelter category and the difference, 0.271 million persons, are forced out. The latter figure is then reduced by FFSM to the 0.264 million shown. It can be seen that the computational program must account for the distribution of survivors with overpressures at each stage in the calculation in order to model survival in a reasonable way.

The Water event (lack of drinking water) applies to the SU and SI population fractions remaining in this shelter category after the Fire event. The principal inputs are FW, the fraction forced out because of lack of drinking water, and FWR, the fraction of those forced out that are afforded remedial radiological measures. Consider those B/C shelters that are remote from the detonation region. Lacking the provision of stored water in specially provided containers, some fraction of these shelters will have ample supplies of drinking water in various storage tanks or may be served by a gravity-pressurized water system that would provide water even if electric power supplies were disrupted. Thus, only a portion of the sheltered population would be in B/C shelters where lack of drinking water could result in premature shelter-leaving. On the other hand, in the area close to detonations, storage tanks and piping would be destroyed and water mains broken. Survivors in this situation would lack drinking water.

In Table A-1, FW_1 is the estimated fraction forced out because of lack of drinking water in the undamaged area. FW_2 is the fraction forced out in the damaged region. PSIFW is the overpressure dividing these two regions. In the example calculations, all survivors experiencing more than 4 psi are forced out as well as half those experiencing lower overpressures. In the calculation shown, most of the injured survivors experience more than the 4-psi level (MCOP = 7 psi). The exception would be the injured survivors that could continue on to B/C shelters after detonations occurred. These were in the 2-3 psi region. In this case, they comprise 0.613 - 0.613 or zero and therefore none remain in the SI column. The equivalent calculation for SU is explained by the fact that some 60 percent of the 2.821 million uninjured survivors are found at overpressures of less than 4 psi when previous deductions in the scenario are taken into account.

The FWR calculation follows a similar pattern. In undamaged areas several days after attack, the effectiveness of remedial movement is seen as quite good —FWR_1 = 0.64—whereas in damaged areas it is seen as quite poor—FWR_2 = 0.02. PSIW defines the boundary of the damaged region as 2 psi in this example. Hence, all of the injured forced out, being in the damaged region, are subject to the 2-percent remedial movement. On the other hand, about 14 percent of the uninjured obtain remedial measures because many are in the undamaged region.

It should be noted that at the conclusion of the Water event all survivors remaining in B/C shelters—some 0.850 million of the risk population—are in overpressure regions below 4 psi as the result of the estimates of FW_2 and PSIFW. These survivors are still subject to premature shelter-leaving because of an untenable heat environment in the shelter areas. This is more likely in summer months than in winter months and more likely in the south and southwest than in the north. As can be seen by the input values in Table A-1, all survivors are forced out in this event (FV = 1.0).

The times at which this movement occurs as well as those for the water event are derived from the analysis of climatological and physiological variables. These times are effective times of shelter-leaving that reproduce the assessment of radiation casualties under variable leaving times in different parts of the country and at different times of the year. In particular, it is not meant that persons afforded remedial movement actually leave shelters earlier than the (N) group but merely that the effective exit time must be shorter to properly reflect the casualty ratio when remedial movement fails.

Because the Ventilation event occurs many days after the detonation, the estimate of FVR_1 is substantially higher—82 percent effective — than FWR_1 in undamaged areas. The effectiveness of remedial measures in damaged areas remains low during this period. Since all occupants in this shelter category have left shelter at the end of the Ventilation event, the final Emergence event is not necessary. Under other assumptions, there would be a group who would ultimately emerge, as the defense scenario procedure requires that all persons leave shelter at some time so that estimates of radiation fatalities and injuries can be made.

Fallout radiation casualties are computed by first calculating an effective protection factor (EPF) for the exposure regime of each group in the Move columns. This process requires other inputs not shown in Table A-1, such as the average protection factor after leaving shelter with and without remedial measures and the like. The resulting EPFs are multiplied by estimates of median lethal dose (MLD) and median sickness dose (MSD) for uninjured and blast-injured persons and the results used in the attack environment matrix to determine the radiation survivors and uninjured among the detonation survivors.

POPDEF Output

The results of the POPDEF casualty computations can be printed out in varying amounts of detail as needed for purposes of analysis. The highest level of aggregation is the national summary, an example of which is shown in Table A-3. Similar summaries can be requested for the three regions: Risk, Host, and Neither. Within each region, detailed printouts can be obtained for each shelter class. The latter are in the format of Table A-1 except for omission of the listing of input parameter values. Each shelter class event tableau is followed by a casualty summary similar to that presented in Table A-3.

The casualty summary consists of three tables in sequence. The uppermost table records total survivors (in millions) by event, as assessed from the "Move" columns of the event tableau. Those persons afforded remedial radiological measures are shown separately from those who are not and, within these categories, those uninjured (MU) and injured (MI) by direct effects. Next in Table A-3 is the record of the subset of survivors who are uninjured from fallout radiation; that is, those whose ERD is less than 200 Roentgens if blast injured or less than 250 R if not injured. The differences between these entries and the corresponding entries in the upper table are those survivors suffering radiation injury.

At the bottom of Table A-3 are the summaries of survivors and fatalities by cause. The "Not Injured" is the sum of the MU columns in the "Radiation Uninjured" table. The blast injured value is the sum of the MI columns in the same table. The radiation injured are obtained from the differences between the MU columns in the two upper tables and those injured by both blast and radiation are obtained in a similar fashion from the MI columns. By dividing any entry by the population base shown at the top of the table, the results can be expressed in terms of fractional survival. In Table A-3, which assumes crisis relocation, the overall survival rate is about 76 percent. About 66 percent of the population survives uninjured. The fatalities are attributable more to blast than to radiation; the "other" fatalities are attributable to fire and lack of rescue.

The MCPOPDEF Application

The POPDEF model outlined above is a short-running though reasonably accurate casualty assessment computer program. It has been implemented at the FEMA Computer Center-Olney. In the process, the casualty assessment program has been linked to a

Table A-3

EXAMPLE POPDEF OUTPUT - DRE, ATTACK B

TOTAL UNITED STATES

POPULATION = 211.774

TOTAL SURVIVORS -

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
RESCUE	.059	.042	.084	1.704
FIRE	.000	.000	.260	.150
WATER	1.549	.065	2.302	2.646
VENT	.450	.000	.737	.002
EMERGENCE	109.817	.072	36.853	3.375
SUBTOTAL	111.876	.179	40.235	7.877

RADIATION UNINJURED -

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
RESCUE	.057	.038	.065	1.224
FIRE	.000	.000	.169	.094
WATER	1.415	.055	1.671	1.789
VENT	..399	.000	.578	.001
EMERGENCE	105.546	.066	30.350	2.588
SUBTOTAL	107.417	.159	32.831	5.696

ULTIMATE SURVIVORS		FATALITIES	
NOT INJURED	140.249	BLAST	31.176
BLAST INJURED	5.855	RADIATION	20.009
RADIATION INJURED	11.862	OTHER	.422
BLAST RADIATION INJURED	2.201		
TOTAL	160.167	TOTAL	51.607

Monte Carlo routine. A description of these programs is contained in Reference 2, along with an overview of the model, a description of the MCPOPDEF/POPDEF input quantities, and a description of the output produced when the model is run in the MCPOPDEF mode.

With respect to the output of MCPOPDEF, Table A-4 may be compared with Table A-3. The numerical results are not comparable because the calculations are for different cases. In the MCPOPDEF mode, the entries are average or mean values of the Monte Carlo runs and standard deviations are provided for the mean values in the final listings of ultimate survivors and fatalities. The MCPOPDEF output is available only for national or regional summaries whereas output at the shelter category level is available for the single POPDEF run.

The complete data input for MCPOPDEF, other than the attack environment matrices (Table A-2), is shown in Figure A-1 for Program D Prime Relocated. This listing shows how technical, operational, and behavioral uncertainties are accounted for in the input parameters of the POPDEF casualty assessment model. Reference 2 describes how probability distributions are generated from the "low," "best," and "high" values of each parameter in the MCPOPDEF version of the model. In the POPDEF version only the "best" values of the input parameters in Figure A-1 are selected by the computer.

Program Analysis Model

The Program Analysis Model (PAM) was developed to provide a means by which appropriate values of the POPDEF input parameters could be estimated, given a description of a postulated civil defense preparedness program. In essence, PAM identifies and defines relationships among elements of civil defense and describes paths through these relationships along which quantitative descriptions of program elements of the preparedness program can be translated into estimates of the POPDEF input parameters. For this purpose, PAM employs (1) a system element structure, (2) a system algebra to define relationships among elements and between elements and other model inputs, and (3) logic diagrams (system trees) that describe how the relationships lead to estimates of the POPDEF input parameters or intermediate inputs.

A sample of the basic system element structure is shown in Table A-5. Major and subordinate elements cover all of the operational and preparedness aspects of the civil defense system. Element codes, such as those shown in Table A-5, are used in

Table A-4

SAMPLE MCPOPDEF CASE OUTPUT LISTING - DRE, ATTACK B

TOTAL UNITED STATES

POPULATION = 211.774

TOTAL SURVIVORS -

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
RESCUE	.059	.038	.070	1.496
FIRE	.002	.002	.292	.162
WATER	.439	.002	.657	.051
VENT	.744	.019	2.120	.568
EMERGENCE	101.365	.157	44.358	5.754
SUBTOTAL	102.611	.217	47.498	8.032

RADIATION UNINJURED -

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
RESCUE	.056	.034	.054	1.074
FIRE	.002	.001	.189	.103
WATER	.362	.001	.471	.034
VENT	.676	.018	1.655	.428
EMERGENCE	96.397	.138	36.784	4.366
SUBTOTAL	97.492	.192	39.153	6.005

ULTIMATE SURVIVORS

	MEAN	STDV
NOT INJURED	136.645	6.563
BLAST INJURED	6.197	.768
RADIATION INJURED	13.463	1.664
BLAST RADIATION INJURED	2.052	.267
TOTAL	158.357	5.670

FATALITIES

	MEAN	STDV
BLAST	32.121	4.271
RADIATION	20.905	3.063
OTHER	.391	.092
TOTAL	53.417	5.670

Table A-5

SAMPLE OF SYSTEM ELEMENT STRUCTURE FOR PROGRAM ANALYSIS MODEL

Major Element	Subordinate Elements	Element Code
Police service	Public preparedness	-
	Self-help	LA
	Warning	LB
	Relocation	LC
	Shelter	LD
	Maintaining order	-
	Facilities	LE
	Relocation traffic	LF
	Movement to shelter	LG
	Remedial movement	LH
	Supressing crime	-
	Controlling access	LI
	Controlling criminals	LJ
	Warning	LK
	Inform D & C	LL
Warden service	Public preparedness	-
	Self-help	WA
	Warning	WB
	Relocation	WC
	Shelter	WD
	Managing movement	-
	Relocation	WE
	To shelter	WF
	Remedial	WG
	Shelter-based operations	-
	Fire fighting	WH
	Rescue	WI
	Remedial movement	WJ
	Managing shelters	-
	Public information	WK
	Improve blast posture	WL
	Improve fallout postures	WM
	Operate ventilation	WN
	Control water use	WO
	Shelter RADEF	WP
	Sanitation	WR
	Medical care	WS
	Feeding	WT
	Reception and care	WX
	Lodging	WU
	Feeding	WV
	Welfare services	WW
	Warning	WY
	Inform D & C	WZ

the logic diagrams. However, a third letter is often added to denote relationships within an element. Thus, for example, DSR is used to designate the fraction of the population for which D & C public information personnel have been recruited, DST refers to those who have been trained, DSS refers to their capability, and DSC refers to the communications they use.

The system algebra used to designate elements and other quantities consists of five relationships. They are:

1. Augmentative: $x = a + b$. This relationship is used whenever one quantity is increased by another without the possibility of double counting, as when the fraction of the population having trained shelter managers now is augmented by the net increase in trained shelter managers at the completion of a postulated program.

2. Independent: $x = a \cdot b$. This relationship obtains when a potential capability is modified by an effectiveness, injury, or other factor and when one capability requires another and there is no logical basis for assuming that they will necessarily be present in the same place.

3. Dependent: $x = \min a : b$. This relationship is used where one capability requires another and there is a logical basis for assuming that they should be present in the same place, as the case where the fraction of the population having trained shelter managers is the minimum of the fraction for which managers have been recruited and the fraction for which managers could be trained.

4. Redundant: $x = a + b - ab$. This relationship applies where there is more than one means of accomplishing a given end as when there are two means of giving attack warning. Some people will be warned by one method and some by the other, but those who are warned by both must be be double-counted.

5. Supportive: $x = x' \{1 - \Delta a(1 - a)\}$. This relationship applies where an element of the system would be able to exercise all of its potential capability (x') if fully supported by the capability, a, of another element and the fraction of x' that would not be realized in the absence of a is estimated to be Δa.

If the supporting element is always required ($\Delta a = 1$), the supportive relationship reduces to the independent relationship.

The foregoing system algebra is employed, along with the element codes and certain notational conventions, in logic diagrams or system trees, such as that shown in Figure A-2. The example shown is the basic system tree for calculating ΔMLOP and ΔMCOP, the change in vulnerability ascribed to the blast protective posture. It will be discussed as a relatively simple example of the PAM methodology.* The analysis begins at lower center with an estimate (or low, best, and high estimates) of the fraction of the population assigned to a public shelter class (or all public shelters) for whom shelter managers are presently recruited (WLR_o). The subscript o is used for initial conditions. Next, an estimate is made of ΔWLR, the net additional fraction for whom managers will be recruited in Program D Prime. For "Current Capability Maintained," this element would be set to zero. Then, WLR, the fraction having managers at program completion would be the sum, as indicated in relationship (1). Similarly, WLT_o is the fraction of the shelter population with managers trained in improving blast posture at present. (This estimate requires investigation of the content of past shelter manager training). ΔWLT is the net fraction for whom shelter managers can be trained in Program D Prime and WLT, the sum, is the fraction of the shelter population with managers trained in improving blast posture at program completion.

Moving up the system tree, WL' is the fraction of the shelter population having shelter managers who would try to improve blast posture, given advice from D & C. This fraction is the minimum of WLR and WLT. WL' is a potential capability because some trained managers may not try to improve blast posture unless reminded by instructions at the time. SP is an estimate of the fraction of managers who would receive such instructions. The blackened corner of the input symbol indicates that this intermediate input is to be calculated by means of another system tree. (The SP system tree has two other intermediate inputs that must be calculated separately.) ΔSP is an estimate of the fraction of shelter population whose trained managers would not try to improve blast posture without guidance from D & C. If this estimate is a small fraction, such guidance is judged not very important. If it is large, guidance from D & C assumes great importance to this function. Relationship (4), then, is the

*The full definitions of the system element structure and the formal development of all the parts of PAM in its current stage of development will be found in Reference 1.

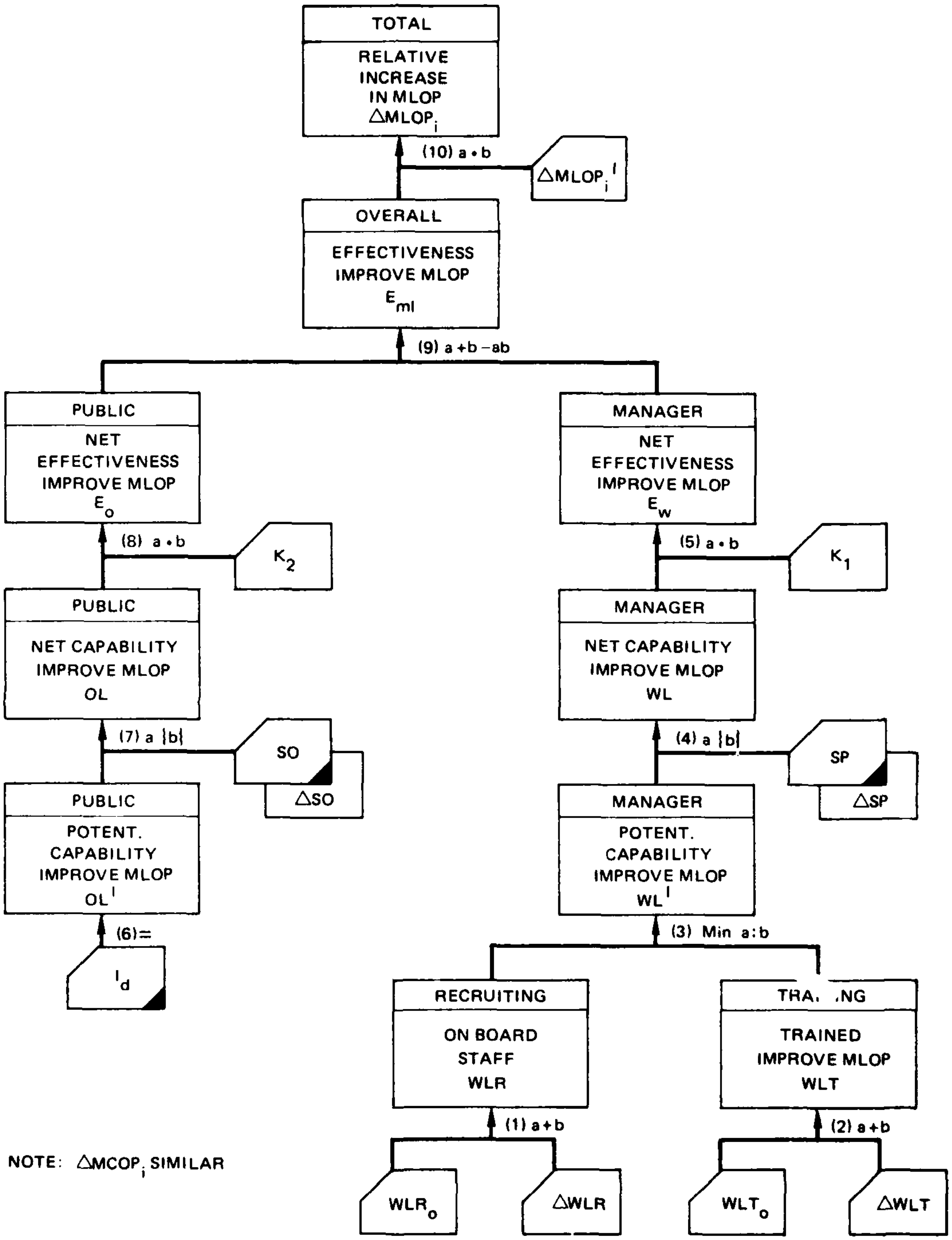

Figure A-2. EFFECTIVENESS IN IMPROVING BLAST PROTECTIVE POSTURE—(ΔMLOP, ΔMCOP) supportive relationship and WL is the net fraction of the shelter population with managers trying to place them in the maximum blast-protective posture.

Of course, not all trained managers may be effective in actually placing the people in the blast-protective posture. Thus, K_1 is an estimate of the relative effectiveness of managers in achieving improved blast posture. WL is multiplied by K_1 to arrive at the fraction of the shelter population in the improved blast posture because of competent managers (E_w).

Some shelters however, may not have a trained manager or an effective one. In this case, there may be an emergent leader who could be effective. This possibility accounts for the left-hand branch of the tree. Given that there exists a public information activity (ID) to prepare the public for shelter occupancy and that some of the public may learn of improving blast posture from this activity, I_d is the net effectiveness of this activity and set equal to OL', the fraction of the shelter public having emergent leaders who would try to improve blast posture, given instructions from D & C. The blackened triangle denotes the I_d is to be estimated through use of a subordinate system tree. The system code, OL does not represent a system element as it concerns an emergent and not a system capability. In PAM, public responses have the initial code letter, O, and a second letter denoting the activity; in this case, L as in *WL in Table* A-5.

As before, SO is an intermediate estimate, developed by means of a separate system tree, of the fraction of emergent leaders who would receive and understand guidance on this activity from D & C. ΔSO is the estimate of the fraction of the shelter population with emergent leaders who would not try to improve blast posture without guidance from D & C. OL is the net fraction with emergent leaders trying to place them in improved blast posture; namely, OL' degraded by the support capability of D & C, relationship (7). K_2 is the relative effectiveness of emergent leaders in achieving the blast-protective posture, which when multiplied by OL yields the fraction of the population in improved blast because of emergent leaders (E_o).

Because the shelter population can be placed in the blast-protective posture by either managers or emergent leaders independently, the overall fraction in the protective posture, $F_{m\ell}$, is the sum of E_o and E_w less their product to avoid double-counting of those with both. Finally, $\Delta MLOP'_i$ is the potential fractional improvement in MLOP for shelter class i, if all occupants were in the blast-protective posture. This is a technical estimate. When multiplied by $E_{m\ell}$, the fraction actually in the posture, one

one obtains the realized increase in MLOP, which is the desired POPDEF input parameter. ΔMCOP is obtained by substituting the technical estimate ΔMCOP' for ΔMLOP'.

As can be seen from this discussion, the PAM methodology is quite detailed and requires numerous estimates of the contributing element capabilities. The documentation of the PAM methodology in Reference A-1 requires about 250 pages. The PAM model produces a number of the POPDEF inputs (e.g., FCR, FR, FPF, FER) shown in Table A-1 and Figure A-1. A complete demonstration of the application of PAM is given in Reference 2.

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Appendix B

ATTACK OPTIONS AND DYNAMICS

Appendix B

ATTACK OPTIONS AND DYNAMICS

The first computerized nationwide damage assessment system was developed for the Federal Civil Defense Administration (FCDA) in 1956 by the Stanford Research Institute (now SRI International).[1] The existence of this new capability generated a requirement for the design of hypothetical attacks to be used to explore the performance of various civil defense options. FCDA and its successor, OCDM, settled on four basic attack options in the late 1950s.[2] The nature of these attack options is shown in Table B-1, taken from Reference 3.

Two options (SA60M and SA60T) were based on estimates of the near-term threat — that of about 1960. The first was a "counterforce" attack of 100 4-MT weapons on SAC bases. The second 1960 hypothetical attack was an attack against both the retaliatory forces and metropolitan areas, using a total of 375 weapons. The military portion of this combined attack was somewhat larger than the counterforce-only attack but most of the additional weapons were directed at cities.

The second pair of options was based on an estimate of the longer-term or future threat — label as pertaining to 1965. These options show an astonishing projection of growth in Soviet strategic power: six times as many weapons (2,300 vs. 375) and a weapon yield of 10 megatons rather than the earlier 4 megatons. This projection reflects the impact of the Sputnik satellite launch and the anticipation of an ICBM "missile gap." Most of the weight of this arsenal (19,000 MT) is directed at retaliatory targets, which were projected to include the Minuteman missile system recommended earlier by the so-called Gaither Panel and set into deployment by the Eisenhower Administration. The attack against cities in the "late combined" attack was increased not only by 150 weapons but by a fourfold increase in megatonnage. In terms of damage-area coverage (EMT), the late city attack was about three times larger than the early city attack.

It is to be noted that the total megatonnage projected as a future threat in 1960 (23,000 MT) greatly exceeds the most robust estimate of the 1985 Soviet threat being made today and even the damaging power (EMT) exceeds the recent 1985 estimates. This illustrates, on the one hand, the difficulties inherent in making realistic

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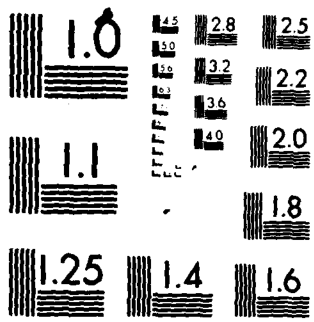

MICROCOPY RESOLUTION TEST CHART
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projections of future threats and attack options and, on the other hand, the tendency to test civil defense program options against the largest hypothetical attacks that could be argued for. Both the inherent difficulty of making reasonable projections and the tendency to test civil defense programs at the limits of "all-out" nuclear war have persisted to the present day.

Table B-1

OCDM ATTACK DESIGNS

	Early Military (SA60M)	Early Combined (SA60T)	Late Military (SA65M)	Late Military (SA65T)
On retaliatory forces				
Number	100	125	1,900	1,900
Yield (MT)	400	500	19,000	19,000
On metropolitan areas				
Number	—	250	—	400
Yield (MT)	—	1,000	—	4,000
Total				
Number	100	375	1,900	2,300
Yield (MT)	400	1,500	19,000	23,000

At the time that Program D Prime was devised, two hypothetical nuclear attacks were used to test the performance of program options. The first was based on the TR-82 risk assessment.[4] For risk assessment purposes, the projected Soviet threat for about 1980 under existing SALT agreements was applied to military, industrial, and population targets. For assessment of risk of direct weapons effects, all weapons were assumed to be airburst; for fallout risk, all weapons were groundburst. The so-called TR-82 attack based on this assessment used the same target system and attack but assumed that half of the weapons were airburst and half were groundburst. An all-groundburst version of this attack was also used in Reference 5, where it is called Attack A. The limitations of this attack for evaluating civil defense program options were that it reflected a largely unMIRVed Soviet threat, did not account for the perceived growth in Soviet strategic offensive capabilities in the 1980s, and did not include some targets believed to be considered important to Soviet planners.

The other attack option available for testing Program D Prime was devised for the Sec Def study that led to the recommendation of Program D Prime. Called Attack 6A, it was used not only in the Sec Def study but also in the first report on the development of the POPDEF model.[6] It was also included in Reference 5 as Attack C. The limitations of this attack option were several. It was a "people-hunting" attack design expressly aimed at population targets created by crisis relocation. It projected a highly-MIRVed Soviet threat of the late 1980s. Despite the projected increase in the Soviet threat, the task of targeting a multitude of small cities in the host areas caused the attack designers to use the Soviet strategic reserve and to shift weapons from more important target systems. These distortions caused it to be criticized as unlikely and unrealistic within the Department of Defense.

A major deficiency in these attack options as well as those used earlier is that they are static attacks; that is, the time of detonation of weapons is unspecified and is treated as if all detonations occurred simultaneously.

This means that certain important elements of civil defense cannot be tested or evaluated. These elements include attack warning, location of shelters relative to population, and measures to expedite movement to shelter. Attack dynamics are essential to assessment of these system elements. In the initial development of the POPDEF model,[6] recourse was made to a 1967 estimate of the rate at which population experienced direct effects.

In view of the foregoing limitations, the scope of work contained in the Introduction to this report contemplated the devising of a set of nuclear attack options appropriate to the mid-1980s for use in testing the design of civil defense programs and the use of these options in conjunction with the POPDEF and PAM models for the analysis of the effectiveness of civil defense program elements. However, several circumstances combined to alter the emphasis that, in consultation with the COTR, was to be accorded this aspect of the work.

Recognition of the deficiencies noted above during the prior work under Contract No. DCPA01-77-C-0223 led to initiation of collaboration with DCPA staff to devise an attack option with the desirable characteristics of Attack 6A but without its distortion of reasonable target values. The resulting option was completed in time to be reported in Reference 5 as Attack B. The combination of Attacks A and B appear to bracket the potential threat sufficiently well that only these two attacks were used in the analysis reported in Reference 7.

Consideration was given to the possibility of producing an attack option reflecting the situation that might pertain in the late 1980s. However, the uncertainties entailed in such an approach seemed too great to accept. The SALT II agreement, now shelved indefinitely, was questionable at the time. The proposed MX missile system would have introduced another major targeting issue similar to that encountered in the late 1950s. Also, the reorganization of emergency preparedness functions under the Federal Emergency Management Agency temporarily limited the access to the DCPA computational facilities. For these reasons and the ready availability of Attack B, it was decided to forego the development of additional options. Attack B has been used in this report in developing the simplified method for the evaluation of program elements and in demonstrating its application.

With respect to the need for a dynamic description of attack effects for use in estimating certain of the POPDEF inputs, this problem was also addressed in the latter stages of the prior work, as reported in Appendix C of Reference 7. Recourse was made to an unclassified paper[8] on the makeup of the Soviet threat anticipated in the 1980s. The total EMT was partitioned among the various Soviet delivery systems. Initial weapon delivery times and salvo characteristics were attributed to each system, again based on unclassified sources. These assumptions permitted the development of attack dynamics reflecting a mid-1980s attack.

During the present work, emphasis was placed on obtaining review and criticism of the attack dynamics methodology and assumptions reported in Reference 7. Comments were invited from analysts in the field and agencies of the Department of Defense with war-gaming responsibilities. Care was taken to keep the discussion on an unclassified basis. There was general agreement that the use of the time-distribution of arrival of EMT as the equivalent of the time-distribution of population experiencing direct effects was reasonable. The assumptions concerning weapons system characteristics employed in Reference 7 were reviewed with interested elements of the Department of Defense and, with the exception of the arrival time (missile range) for the

Delta-1 class submarines, were found to be such as not to detract from the validity of the study conclusions.

The significance of the exception noted is that the Delta-1 class and its associated EMT was included, along with the Yankee-class submarines, in the short-range threat; the Delta-2 and Delta-3 classes were assumed to be the long-range threat. We interpret the exception to mean that all of the Delta boats should be considered in the long-range category rather than the short-range category. This change would reduce the short-range (and, hence, earliest arriving) weapons from 6 percent of the total EMT to 4 percent. Correspondingly, the long-range and later-arriving threat would increase from 7 percent to 9 percent of total EMT. The resulting changes in the slow, medium, and fast attacks shown in Figure C-3 of Reference 7 are not significant. In the "slow" attack, the short-range submarine threat is held in reserve. The long-range SLBMs are the first to arrive, beginning about 15 minutes after launch. This salvo would build to include 9 percent of the total direct-effects population rather than 7 percent and this 2 percent increase would be reflected in the remainder of the cumulative time-distribution.

In the medium-speed war, or "best estimate" of attack dynamics, the long-range SLBMs were held in reserve and the short-range threat used to strike C^3 facilities and counterforce targets. The short-range SLBMs would begin arriving at about six minutes after launch as before but would build to only 4 percent rather than 6 percent due to the withdrawal of Delta-1 EMT to reserve. This 2 percent decrease would be reflected in the remainder of the cumulative time-distribution. In the high estimate or "fast" attack, no threat element is held in reserve. The movement of the Delta-1 class boats from short-range to long-range tends to flatten the buildup of EMT between six minutes and 28 minutes. Thereafter the cumulative time-distribution is unchanged. In summary, the effect of this change on the calculation of FS and FE for use in the POPDEF model was found to be negligible.

On the other hand, one unclassified estimate was found in the recent literature that postulated a significantly different makeup of the 1985 Soviet threat than that of Reference 8. This estimate was contained in the prepared statement of Paul H. Nitze before the House Committee on Armed Services on November 15, 1979. As part of this statement, Mr. Nitze made a comparison of U.S. and U.S.S.R. strategic offensive forces as he believed they would be in 1985. The key Soviet characteristics as projected by Nitze and by Burke[8] are:

	Burke		Nitze	
	EMT	Percent	EMT	Percent
ICMs	5995	79%	6686	72%
SLBMs	956	13	2216	23
Bombers	550	8	420	5
Total	7201	100%	9322	100%

It can be seen that Nitze projects a total force level greater than that of Burke by over 2100 EMT. The impact on attack dynamics lies in the fact that most of this increase is allocated to the submarine-launched missiles (SLBMs). As a consequence, the submarine part of the total threat rises from Burke's 13 percent to 23 percent. The ICBM and bomber threats are correspondingly reduced. If the Nitze estimates were adopted, about 10 percent of the total population brought within the direct-effects region by the attack might be affected before 30 minutes rather than later. This change would have a significant effect on both FS and FE, reducing the fraction of the population in shelter at the time of onset of weapon effects.

Since the inputed increase in the SLBM share of the total threat would be in the modern long-range Delta boats, the actual effect on the attack dynamics would depend on the projected strategic use of the long-range SLBM threat. In Reference 7, this threat is employed in the "slow" and "fast" wars but is held in reserve in the "medium" or "best estimate" attack. Hence, both the slow and fast attacks would lay weapons down somewhat faster but the best estimates would not change. In other words, the FIS equations developed in this study still would be applicable.

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Appendix C

RESULTS OF CALCULATIONS

Appendix C

RESULTS OF CALCULATIONS

This appendix describes the calculations and presents the results that were used in Sections II and III. The form of the PAM calculations and the values of the PAM input estimates for the D Prime and Current Capability Maintained programs are given in Reference 3. POPDEF estimates of survival were calculated for Attack B of Reference 3.

The sets of calculations developed for this study were:

- POPDEF calculations in which the inputs for Program D Prime were varied as a basis for analyzing the sensitivity of the survival estimates to changes in the inputs to the model.
- POPDEF calculations in which the values of the input factors were varied for a series of postures to obtain data for the development of the simplified method described in Section II.
- PAM calculations to obtain estimates of POPDEF input factors for use in development of the simplified method and in analyzing the performance of program elements in Section III.
- Calculations of program element performance using the simplified method.

Sensitivity Calculations

Development of a simplified method of obtaining estimates of program element performance required the examination of the relative contributions of these program elements to the overall performance of Program D Prime. This was done by means of a set of POPDEF calculations at the FEMA Computer Center-Olney. In each of these calculations, one of the POPDEF inputs was set equal to zero and the remaining inputs left at their Program D Prime-Relocated (DRE) values. Calculations were made only for the "Best" estimates of Reference 3.

These calculations are relatively simple. The input data for MCPOPDEF calculations for Program D Prime-Relocated (DRE) are stored in the FEMA computer under the name P1.RELOC. These data are as displayed in Figure A-1. To produce the input for one of the POPDEF sensitivity calculations requires the changing of only the values to be set equal to zero. For example, to set FPF = 0, P1.RELOC would be modified only in those lines shown as zeros in Figure C-1.

The results of the calculations are shown in Table C-1. It should be noted that some of the terminology described in Appendix A has been modified in the table. The term "Fraction in Shelter (FIS)," which is defined in Section II, has been substituted for "Fraction Who Are Stayputs (FS)." In evaluating shelter postures, it is more significant to concentrate attention on the extent to which the posture is used. The quantity FIS is better suited to this purpose.

The term "Fraction Achieving Improved Blast Posture (EML)" has been substituted for MLOP and MCOP, which are inputs to the POPDEF model. The terms MLOP and MCOP are calculated from EML and vary with it. The use of EML simplifies the presentation.

Table C-1 shows the results of the calculations in fractions of the population and millions of survivors for a 1975 population of 211.774 million.

Table C-1

RESULTS OF SENSITIVITY CALCULATIONS
(DRE - Attack B)

	Uninjured Survivors		Total Survivors	
Factor Set Equal to Zero	Millions	Fraction of Population	Millions	Fraction of Population
FCR	76.657	0.362	100.940	0.477
FIS	74.263	0.351	108.384	0.512
EML	138.908	0.656	159.842	0.755
FF	140.194	0.662	160.329	0.758
FPF	134.855	0.637	158.097	0.747
FFR	140.249	0.662	160.167	0.756
FWR	139.722	0.660	160.114	0.756
FVR	139.463	0.659	159.922	0.755
FER	116.901	0.552	147.878	0.698

Input Factor Variation Calculations

As discussed in Section II, the immediate result of the sensitivity analysis was a conclusion that four POPDEF input factors (FCR, FIS, FPF, and FER) could fairly

MCPOPDEF INPUT For PROGRAM ___ORE except FPF = 0___ 3 of 5

		Line								
Area			Risk			Host			Neither	
Estimate			Low	Best	High	Low	Best	High	Low	Best
Area			Neither					Output ___DFO___.		
Estimate			High					File______		
Fractional Increase in MLOP = ΔMLOP; Fractional Increase in MCOP = ΔMCOP — Shelter Class 5 E/S	ΔMLOP	96								
		97								
	ΔMCOP	98						Use ___RELOC___ Input		
		99								
Shelter Class 6 G/H/S	ΔMLOP	100						Use ___AEM 9___		
		101								
	ΔMCOP	102								
		103								
Shelter Class 7 XU	ΔMLOP	104								
		105								
	ΔMCOP	106								
		107								
Shelter Class 8 Y	ΔMLOP	108								
		109								
	ΔMCOP	110								
		111								
Shelter Class 9 XC	ΔMLOP	112								
		113								
	ΔMCOP	114								
		115								
Shelter Class 10 Open	ΔMLOP	116								
		117								
	ΔMCOP	118								
		119								
ΔPF	Shelter Class		1	2	3	4	5	6	7	8
			9							
Fract. Increase in Rated PF		120								
		121								
Fraction with Incr. PF - BPF	Estimate		Low	Best	High					
Area R, Shelter Class	R/D	122		0						
	other	123		0						
Area H, Shelter Class	R/D	124		0						
	other	125		0						
Area N, Shelter Class	R/D	126		0						
	other	127		0						
FTU	Shelter Class		1	2	3	4	5	6	7	8
			9							
Fract. Trapped Surv. Uninjured		128								
		129								
Fraction Rescued - FR, Estimate	Low	130								
		131								
	Best	132								
		133								
	High	134								
		135								
PSIR		136								

Figure C-1. FPF=0 IS SET BY MODIFYING P1.RELOC ONLY IN LINES SHOWN AS ZEROS represent a civil defense program for the purpose of evaluating alternatives among the program elements. As a result of this conclusion, the investigation of the variation in performance estimates with respect to the variation in POPDEF inputs was limited to these four factors.

For this investigation a series of POPDEF computer calculations was made in which sensitivity calculations were made for a number of different modes, all based on Program D Prime. The programs for which calculations were made are described in the following:

- o No Relocation (DPRO). Program D Prime with FCR equal to zero (FCR = 0). For this case, other POPDEF input factors were given the values previously calculated for the in-place mode.

- o D Prime In Place (DIP). Program D Prime without a Presidential Declaration (FCR = 0.27). For this case POPDEF input factors were given the values previously calculated for DIP.[3]

- o Direction and Control = Zero (DCO). Program D Prime Relocation with new POPDEF input factors for which PAM calculations were affected by setting PAM inputs to values consistent with no program elements for Direction and Control (FCR calculated = 0.57). Other POPDEF input factors were given their values for Program D Prime Relocated (DRE).[3]

- o Direction and Control = CCM (DCC). Program D Prime Relocated with new POPDEF input factors for which PAM calculations were affected as in DCO but with the PAM inputs given values consistent with program elements for Direction and Control as in the Current Capability Maintained (FCR calculated = 0.69). Other POPDEF input factors were given their values for DRE.[3]

- o Program D Prime Relocated (DRE). Program D Prime with relocation given a Presidential Declaration. Other POPDEF input factors were given their values that were calculated previously.[3]

- o Complete Relocation (DRI). Program D Prime with complete relocation (FCR = 1.0). Other POPDEF input factors were given their DRE values.

Calculations were made for each case as described and then, for each case, FIS, FPF, and FER were set equal to zero, one at a time, and new POPDEF calculations made. The results of these calculations are given in Table C-2.

Table C-2

VARIATION IN SURVIVAL ESTIMATES
(Fractions of Population - Attack B)

	Estimated Uninjured Survival			
Case	Total	FIS = 0	FPF = 0	FER = 0
DPRO	.362	.163	.354	.317
DIP	.468	.234	.457	.415
DCO	.499	.304	.491	.480
DCC	.605	.336	.587	.525
DRE	.662	.354	.636	.552
DRI	.749	.411	.719	.618

	Estimated Total Survival			
Case	Total	FIS = 0	FPF = 0	FER = 0
DPRO	0.477	0.290	0.472	0.451
DIP	0.576	0.376	0.570	0.549
DCO	0.634	.0452	0.630	0.624
DCC	0.712	0.488	0.705	0.669
DRE	0.757	0.512	0.747	0.699
DRI	0.837	0.581	0.826	0.769

Calculations were not made for FCR = 0 except in the DPRO case because, as can be seen in Section II, the effect of varying FCR can be found without these estimates.

Input Factor Calculations

As noted above, new POPDEF input factors were calculated for the DCO and DCC cases. These calculations were made by reviewing the previous PAM calculations, entering the appropriate input values for DCO and DCC, and recalculating the PAM output. These new calculations followed the method described in Reference 3 and, except where changes in inputs were required, used the values shown there.

In addition, POPDEF input factors were calculated, where necessary, for the individual elements of Program D Prime giving each the appropriate PAM inputs consistent with its CCM statue. The considerations applied in these calculations were as follows:

- Direction and Control (DC). DC directly affects system operations through only two system elements: System Information Capability (DZ) and Public Information Capability (DS). In addition, DC indirectly affects FIS because the change in fraction relocated (FCR) changes the fractions of the population in the risk and host areas which, in turn, changes the distribution (FA) of people to the several classes of shelter. And because the fraction of population that stays put varies between public shelter and home basements, this change in distribution also causes a change in FIS. DC affects all four of the input factors.

- Citizen Training (CCT). The preparedness of the people for taking action to assist can affect all emergency operations in which they can participate. In this case, CT affects all four input factors directly through the system elements IA, IB, IC, and ID and it affects FIS indirectly, as in the case of DC above.

- Emergency Broadcasting (EBS). Protection of emergency broadcast stations can affect performance only of operations after the attack, in this case, only FPF and FER. The effects of EBS are accounted for in PAM through the system element IE.

- Radiological Monitors (RDM). Monitoring also can affect only the after-attack terms FPF and FER. Monitor training is accounted for in PAM through system elements WP, UB, and UD.

- Radiological Instruments (RDI). Availability of radiological instruments similarly can affect only FPF and FER. RDI is accounted for in PAM through system elements UA, UC, and UE.

- Wardens (WRD). In the POPDEF/PAM method, shelter managers are assigned "Warden Service" functions in connection with crisis relocation, movement to shelter, shelter-based operations outside the shelters, and citizen training, in addition to their function of managing activities within the shelters. Therefore, shelter manager recruiting and training can affect all four of the input factors. In addition, WRD indirectly affects FIS as described in the discussion of DC above. WRD is accounted for in PAM through the Warden Service system elements.

- Operations Plans (PB). Availability of operations plans can directly affect all four input factors and can indirectly affect FIS as discussed above. Operations Plans are accounted for in PAM through the system element PB.

- Organization Exercise (PI). Similarly, conduct of exercises of the emergency organization can affect all four input factors directly and FIS indirectly. Exercises are accounted for in PAM through the system element PI.

When the appropriate CCM values are introduced in PAM through the system elements identified above, the calculated values of FCR, FIS, FPF, and FER for use in Equations 2.11 and 2.12 are as shown in Table C-1.

The POPDEF model prepares separate calculations for each of the classes of shelter for Risk, Host, and Neither areas and then summarizes the separate estimates into totals. To accomplish this, POPDEF requires PAM estimates in various levels of detail but, notably for this analysis, (a) for public shelters and home basements in (b) Risk, Host, and Neither areas, a total of six sets. Of course, only one estimate is required for FCR. If the "simplified" calculation were to continue this approach, it would require six separate calculations plus the summarizing of the results.

However, this can be avoided by combining the separate values for each factor into one that represents the total population. This is done by taking the average of the separate values for the factor weighted by the fractions of the population to which they apply. Then, in Figure C-2, to find the combined value of FER, the calculation would be:

Risk	.02 x .540	=	.011	
	.01 x .460	=	.005	
			.016	x .150 = .002
Host	.82 x .865	=	.709	
	.57 x .135	=	.077	
			.786	x .837 = .658
Neither	.74 x .501	=	.371	
	.44 x .499	=	.220	
			.591	x .031 = .008
				FER = .668 say, 0.67

POPDEF INPUTS

Case Program D Prime - Relocated · DRE

Estimate Low ____ Best ✓✓✓ High ____

Factor		Risk	Host	Neither	Mean			Risk	Host	Neither
						Population Distribution				
						T	1.0	0.150	0.837	0.013
						P	0.812	0.540	0.865	0.501
FCR					0.77	H	0.188	0.460	0.135	0.499
FS	P	0.12	0.05	0.05						
	H	0.11	0.05	0.05						
FIS	P				0.92			0.361	0.822	0.476
	H							0.228	0.128	0.474
	Y							0.130		
FE		0.03			0.02					
EML	P	0.08	0.66	0.58	0.53	A	ΔML	–	0.07	0.06
							ΔMC	–	0.07	0.06
						B/C	ΔML	0.03	0.23	0.20
							ΔMC	0.03	0.23	0.20
						E/F	ΔML	–	0.07	0.06
							ΔMC	0.08	0.66	0.56
						G/H/I	ΔML	0.04	0.40	0.34
							ΔMC	0.04	0.33	0.28
	H	0.04	0.30	0.30		D	ΔML	0.01	0.05	0.05
							ΔMC	0.04	0.27	0.27
FPF	P	0.05	0.84	0.79	0.65	FA - Shelter Assignment				
	H	0.02	0.23	0.23		Random		0.204	–	–
FFR	P	–			–	D		0.256	0.135	0.499
	H	–				A		0.054	0.034	0.010
FWR	P	0.02	0.64	0.64	0.50	B/C		0.293	0.155	0.267
	H	0.01	0.22	0.22		E/F		0.043	0.030	0.028
FVR		0.07	0.82	0.77	0.60	G/H/I		0.020	0.101	0.071
FEA	P	0.02	0.82	0.74	0.67	XU		–	0.545	0.125
	H	0.01	0.57	0.44		Y		0.130	–	–
								FP	FFS	FR
FP					0.08	Random		0.03	1.0	0.97
						D		0.13	0.98	0.74
FFS					0.99	A/XI/Y		–	–	1.0
						B/C		0.11	0.99	0.75
FR					0.85	E/F		0.10	0.99	0.81
						G/H/I/XU		0.03	1.0	0.97

Figure C-2. EXAMPLE OF POPDEF INPUTS

The combined value for FPF would be calculated in the same manner. FIS is calculated in a somewhat different way. The factor FIS represents the fraction of the population who would reach the assigned shelters (A, B/C, D, E/F, G/H/I, XU, and Y). Then,

$$
\begin{array}{llllll}
\text{Risk} & FIS(P) & = & FA(P)(1 - FS(P)) & & \\
 & & = & (0.54 + 0.293 + 0.043 + 0.020)\,(1 - 0.12) & & \\
 & & = & & & 0.361 \\
 & FIS(H) & = & 0.256(1 - 0.11) & = & 0.228 \\
 & FIS(Y) & = & 0.130(1 - 0) & = & \underline{0.130} \\
 & & & & & 0.719
\end{array}
$$

$$
\begin{array}{llllll}
\text{Host} & FIS(P) & = & 0.865 \times (1 - 0.05) & = & 0.822 \\
 & FIS(H) & = & 0.135 \times (1 - 0.05) & = & \underline{0.128} \\
 & & & & & 0.950
\end{array}
$$

$$
\begin{array}{llllll}
\text{Neither} & FIS(P) & = & 0.501 \times (1 - 0.05) & = & 0.476 \\
 & FIS(H) & = & 0.499 \times (1 - 0.05) & = & \underline{0.474} \\
 & & & & & 0.950
\end{array}
$$

$$
\begin{array}{lllll}
FIS & = & 0.150 \times 0.719 & = & 0.108 \\
 & = & 0.837 \times 0.950 & = & 0.795 \\
 & = & 0.013 \times 0.950 & = & \underline{0.012} \\
 & & & & 0.915 \text{ say, } 0.92
\end{array}
$$

Because the estimated fraction of stayputs (FS) is the same for public shelters and home basements in the Host and Neither areas, the calculation need not have been as extensive as shown in the example. However, the full calculation is shown because differing values might apply in other cases.

The combined input factors for the cases and program elements listed above were calculated to be as shown in Table C-3.

Table C-3

COMBINED POPDEF INPUT FACTORS

Case or Elements	FCR	FIS	FPF	FER
DPRO	0	0.78	0.46	0.33
DIP	0.27	0.83	0.58	0.44
DCO	0.57	0.88	0.32	0.12
DCC	0.69	0.90	0.50	0.49
DRE	0.77	0.92	0.65	0.67
DRI	1.0	0.95	0.77	0.79
DC	0.69	0.90	0.50	0.49
CCI	0.76	0.90	0.64	0.63
EBS	0.77	0.92	0.63	0.66
RDM	0.77	0.92	0.31	0.66
RDI	0.77	0.92	0.61	0.67
WRD	0.72	0.91	0.57	0.44
PB	0.72	0.91	0.61	0.63
PI	0.75	0.91	0.65	0.64
(CCM)	0.16	0.47		

As demonstrated in Section III, the performance of the other program elements (CRP, SHL, SK, and SJ) cannot be calculated by applying the four POPDEF input factors directly. Therefore, these elements have been omitted from Table C-3.

Calculation of Program Element Performance

Calculation of the performance of individual program elements as described in Section III was accomplished using the simplified method developed in Section II. For example, to find the increase in survival, uninjured and total, ascribed to Wardens (WRD) for DRE over CCM, the equations derived in Section II were applied as follows using the values for WRD in Table C-3:

o Uninjured survivors:

$$U_{DRE} = 0.247 \times 0.77 + 0.150 \times 0.92 + 0.052 \times 0.65 + 0.171 \times 0.67 + 0.081 = 0.658$$

$$U_{W} = 0.247 \times 0.72 + 0.150 \times 0.91 + 0.052 \times 0.57 + 0.171 \times 0.44 + 0.181 = \underline{0.600}$$

$$\text{Increase (DRE over CCM)} = 0.058$$

o Total survivors:

$$T_{DRE} = 0.286 \times 0.77 + 0.131 \times 0.92 + 0.017 \times 0.65 + 0.091 \times 0.67 + 0.341 = 0.752$$

$$T_{W} = 0.286 \times 0.72 + 0.131 \times 0.91 + 0.017 \times 0.57 + 0.171 \times 0.44 + 0.341 = \underline{0.714}$$

Increase (DRE over CCM) = 0.038

Then, the total survival, uninjured and injured, and the increase in survival for the program elements listed in Table C-2, were found to be as shown in Table C-4.

In Table C-4, the survival and the increase in survival shown for the cases (DPRO, DIP, etc.) over CCM are from the POPDEF calculations. The survival and the increase in survival for the elements (DC, CCT, etc.) are from the calculations using the simplified method. Thus the increases attributed to the elements are related to the estimates for DRE calculated by the simplified method. This is appropriate because in using such estimates for evaluating alternatives within program elements, their relative values are more important than their absolute values.

Table C-4

CALCULATED SURVIVAL—PROGRAM D PRIME
(Fractions of Population - Attack B)

Case or Element	Uninjured Survival		Total Survival	
	Survival	Increase*	Survival	Increase*
DPRO†	0.362	0.098	0.477	0.076
DIP†	0.468	0.204	0.576	0.175
DCO†	0.499	0.235	0.634	0.233
DCC†	0.605	0.341	0.712	0.311
DRE†	0.662	0.398	0.757	0.356
DRI†	0.749	0.485	0.837	0.436
DC‡	0.596	0.062	0.708	0.044
CCT‡	0.645	0.013	0.743	0.009
EBS‡	0.655	0.003	0.751	0.001
RDM‡	0.638	0.020	0.746	0.006
RDI‡	0.655	0.003	0.751	0.001
WRD‡	0.600	0.058	0.714	0.038
PB‡	0.635	0.023	0.753	0.020
PI‡	0.645	0.012	0.742	0.010
DRE‡	0.658	—	0.754	0.353
(CCM)‡	0.264	—	0.401	—
(OCD)‡	0.162	—	0.276	—

* Over CCM

† POPDEF Estimates

‡ Simplified Method Estimates

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ANALYSIS OF EFFECTIVENESS OF CIVIL DEFENSE PROGRAM ELEMENTS
John F. Devaney and Walmer E. Strope

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June 1980, 110 pp. Contract DCPA01-79-C-0247

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