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INSTRUMENTATION REQUIREMENTS FOR RADIOLOGICAL DEFENSE OF THE U.--ETC(U)

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Instrumentation Requirements for Radiological Defense of the U.S. Population in Community Shelters

FINAL REPORT, AUG[redacted]78

Carsten M. Haaland
Kathy S. Gant

Interagency Agreement DOE-40-595-76
and DCPA-01-76-C-0367, Work Unit 2131A

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INSTRUMENTATION REQUIREMENTS FOR RADIOLOGICAL DEFENSE OF THE U.S. POPULATION IN COMMUNITY SHELTERS

Final Report

by

Carsten M. Haaland and Kathy S. Gant

and

Principal Computer Programmers

Richard S. Dillion and Betsy M. Horwedel

for

Defense Civil Preparedness Agency
Washington, DC 20301

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DCPA Review Notice

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Oak Ridge, Tennessee 37830
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INSTRUMENTATION REQUIREMENTS FOR RADIOLOGICAL DEFENSE OF THE U.S. POPULATION IN COMMUNITY SHELTERS

Carsten M. Haaland and Kathy S. Gant

DETACHABLE SUMMARY

Allocation of radiological instruments was based on a computer simulation of a Community Shelter Program (CSP) posture. This simulation combined for the first time data consisting of National Shelter Survey (NSS) data, the Bureau of the Census 1970 count of home basements, the 1970 residential population, the CRP-2B hypothetical nuclear attack, and geographical coordinates for each of 42,000 Standard Location Areas (SLAs) throughout the United States. This detailed data base allowed the estimation of the number of NSS facilities and spaces occupied within a specified radius from a given SLA.

The allocations of radiological instruments for the CSP mode were based on a shelter posture in which all NSS shelters in the home SLA and empty NSS spaces in adjoining SLAs within a 1-mile radius could be occupied. Home basements were shared, with up to 50 people per basement, in areas where there were insufficient NSS shelter spaces. Aboveground NSS spaces and those with a protection factor (PF) less than 40 were not used in SLAs in which the blast overpressure from the CRP-2B attack would be 2 psi or greater. In this posture, 31% of the U.S. population was sheltered in NSS shelters, 60% in home basements, and 9% in neither. Of 36 million home basements, approximately one million were shared with nonresidents. Only 18% of the total NSS shelter spaces were utilized because of the elimination of aboveground spaces in risk areas and the 1-mile distance restriction.

Occupied NSS shelters were categorized by number of occupants to provide a basis for instrument allocation. Thirty-seven percent of the occupied NSS shelters had less than 50 occupants each, and six percent had an average occupancy of about 2300.

The instruments necessary to provide a bare minimum of radiological defense were 3.4 million dosimeters, 1.3 million chargers, and 1.4 million ratemeters, for a total estimated cost of about $75 million. Such a deployment of instruments does not provide for the recording of individual dose that is needed for postattack recovery. The smallest numbers of instruments required to provide individual records of dose were 18.1 million dosimeters, 1.9 million chargers, and 1.4 million ratemeters, at an estimated cost of about $228 million. Costs are based on projected mass production of thermoplastic electroscope dosimeters and ratemeters and a piezoelectric charger, all in development at present.

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Based on a detailed computer simulation of a Community Shelter Plan posture, it is estimated that 3.4 million new dosimeters and 1.4 million new ratemeters would be required for radiological defense. To maintain dose records for all shelter occupants, 18.1 million new dosimeters and 1.4 million new ratemeters would be required.

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GLOSSARY OF ACRONYMS

BF	-	Basement Fraction
BG	-	Belowground
BSMT	-	Basement
BP	-	Basement Preference
CD	-	Civil Defense
CDC	-	Control Data Corporation
CONUS	-	Continental United States
COTR	-	Contracting Officer's Technical Representative
CPG	-	Civil Preparedness Guide
CRP	-	Crisis Relocation Planning
CSP	-	Community Shelter Program
DCPA	-	Defense Civil Preparedness Agency
DOE	-	Department of Energy
ED	-	Enumeration District
EMP	-	Electromagnetic Pulse from nuclear weapon detonation
EOC	-	Emergency Operating Center
IBM	-	International Business Machines
ICBM	-	Intercontinental Ballistic Missile
keV	-	Kilo-electron Volt
LED	-	Light Emitting Diode
MED	-	Master Enumeration District
MED-X	-	Master Enumeration District Extended with geographical coordinates
MEV	-	Mega-electron Volt
NAS	-	National Academy of Sciences

NCRP	-	National Council on Radiation Protection
NSS	-	National Shelter Survey
OCD	-	Office of Civil Defense
OCDM	-	Office of Civil and Defense Mobilization
ORNL	-	Oak Ridge National Laboratory
PF	-	Protection Factor
PV	-	Physical Vulnerability
RADEF	-	Radiological Defense
R/NR	-	Risk/Non-Risk
RSAC	-	Region, State, and Area Code
SLA	-	Standard Location Area
SMSA	-	Standard Metropolitan Statistical Area

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*A Glossary of Acronyms for this report begins on page ix.

INSTRUMENTATION REQUIREMENTS FOR RADIOLOGICAL DEFENSE OF THE U.S. POPULATION IN COMMUNITY SHELTERS

Carsten M. Haaland
Kathy S. Gant

ABSTRACT

Estimates are made of requirements for instruments for radiological defense of the U.S. population in the event of a nuclear attack. A detailed Community Shelter Plan posture is developed for each of 42,000 Standard Location Areas. Travel distance from residence to shelter in urban areas is limited to approximately 1 mile. Sixty percent of the U.S. population is sheltered in home basements, thirty-one percent in National Shelter Survey shelters, and nine percent is in neither. Three minimum allocations of instruments are developed. Allocation A, one radiological defense set per shelter, is essentially the same as the current civil defense allocations but is found to be inadequate for about 100,000 shelters having more than 100 occupants. Allocation B requires 3.4 million new dosimeters based on estimated shelter occupancy and provides a minimum instrumentation for radiological defense but not enough instruments to maintain individual dose records. Allocation C would require 18.1 million new dosimeters and would provide adequate instrumentation to maintain dose records for all shelter occupants.

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1. INTRODUCTION

This report presents the results of research performed at Oak Ridge National Laboratory for the Defense Civil Preparedness Agency (DCPA*) on the problem of determining radiological instrument requirements for the people of the United States in the event of a nuclear attack. It is generally recognized that the life-saving potential of fallout shelters in the aftermath of a nuclear attack can be negated if the occupants have no way of knowing to what degree they have been exposed to ionizing radiation from fallout or how intense the radiation may be outside the

*A Glossary of Acronyms for this report is given on pages ix and x.

shelter. Without this knowledge, people may not select the best protected areas and may possibly receive excessive exposure, or they may leave the shelter too early, with the same disastrous consequence. For these reasons it is considered necessary to have instruments in the shelters for detecting and measuring ionizing radiation.

The specific problem is defined by the scope-of-work statement from DCPA, which is quoted as follows:

> "The Health Physics Division of Oak Ridge National Laboratory (ORNL) in coordination and consultation with DCPA, shall study and determine the qualitative and quantitative requirements for local radiological defense (RADEF) for the shelter-in-place mode of Nuclear Civil Preparedness planning. This shall include but not be limited to requirements for training of personnel, equipment, facilities, and procedures necessary for the assessment of the radiological hazards encountered by shelterees as a result of a nuclear weapons attack on CONUS."
>
> "The work to be performed shall use, as a starting point, the model for a local RADEF system as presented in the draft CPG, 'The Local RADEF System.' The project shall address primarily the Shelter Monitoring and Monitoring and Reporting subsystems, as described therein. Relationship with other subsystems during all operational phases shall be developed. Alternatives for providing the necessary training and equipment, including radiological instruments, shall be explored and presented."

The draft Civil Preparedness Guide (CPG) referred to in the scope of work has been finalized by DCPA and published as CPG 2-6.1, Radiological Defense Preparedness (Department of Defense, 1978). Only slight changes in terminology and organization have been made that affect the scope of work stated above. For example, in the CPG 2-6.1 dated April 1978, the recommended model for a local RADEF system must include the four following subsystems (or capabilities): (1) shelter radiological monitoring; (2) monitoring, reporting, and assessment; (3) self-protection radiological monitoring; and (4) radiological decontamination.

A summary of the work performed, conclusions, and recommendations are given in Sect. 2. The requirements for RADEF instruments in shelters and the relationship of these requirements to the various subsystems are described in Sect. 3.

The final section presents three alternate estimates of requirements for radiological instruments in occupied NSS shelters and in home basements where shelter space is shared with nonowners.

Appendices A and B include some considerations and recommendations made by the National Academy of Sciences on requirements for radiological instruments.

An estimate is made in Appendix C of the number of home basements which would be used as shelters and shared with people other than the usual residents.

One of the major tasks of this project was to estimate the distribution of people in NSS (National Shelter Survey) shelters and in home basements, as they might be distributed in the "shelter-in-place mode of Nuclear Civil Protection (NCP) planning." In this mode, also sometimes referred to as the CSP (Community Shelter Plan), people are assumed to take the best available shelter against radiation from nuclear fallout in buildings which are near their residences, not more than a mile or two in urban areas. The preparation of the data base for the location, size, and protection of both NSS shelters and home basements is described in Appendix D. This data base is the first one, to our knowledge, to combine both types of shelters in a common data base in such a way that all shelters of both types within a specified radius (on the order of a few miles) from a specific location can be quickly listed with a large computer. Estimates of the distribution of people within these shelters are described in Appendix E.

In order to obtain better approximations of the "shelter-in-place mode," two variations of the NSS data base were also investigated. In one of these variations, only belowground spaces were used throughout the nation, and in the other, the NSS data base was modified within areas considered to be at high risk of blast damage in a hypothetical nuclear attack. The modification consisted in deleting aboveground spaces and all spaces with a PF less than 40.

2. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

2.1 Summary and Conclusions

Radiological instruments, dosimeters, and ratemeters (survey meters) are necessary to maximize the life-saving potential of fallout shelters. Measurements of radiation intensity in various locations within shelters and knowledge of the dose accumulated by occupants are essential to avoid possible fatal exposure to ionizing radiation. The Penalty Table (NCRP, 1974) sets up convenient limits for dose accumulation in terms of requirements for medical care and possible fatalities. Data from radiological instruments can be used in conjunction with these guidelines to reduce fatalities and control radiation injury.

Numerous parameters affect the estimation of the number of instruments required for shelters. Some of the more important ones are the availability of instruments and their cost; the number, size, and average PF (protection factor) of the shelters; the number of occupants expected to use each shelter; and shelter management. Information was available on all of these parameters except shelter management.

Shelter management, that is, organization of the shelter occupants into units (generally 7 to 12 people), will depend on shelter configuration, variability of PF, and the average PF of the shelter. The existence of a number of small rooms in the shelter, great variability of PF, or a low average PF (<40) may require organization of the shelter population into smaller units (6 to 7 members) for better control; a correspondingly larger number of instruments would become necessary. Data in computer-usable form were not available on shelter configuration and the variability of PF within shelters. For this study it was assumed that shelter units would average ten people.

In order to evaluate the number of occupants expected to use each shelter, a shelter availability data base was prepared. This data base combined for the first time on a detailed geographical basis the NSS (National Shelter Survey) data base from DCPA with the home basement data obtained by the Bureau of the Census 1970. These data were combined with the 1970 population and associated with the coordinates of the geographical centroid for each of the 43,000 Standard Location Areas (SLAs) of the U.S.

Two secondary data bases were also prepared, each involving a reduction in the public shelter spaces available. In one case, only belowground NSS spaces were available. In the other, all public shelters outside areas at risk from blast (as determined by the hypothetical CRP-2B attack) were included. In blast areas, special facilities (caves, mines, and tunnels) and the better belowground spaces were used. All home basements, including those in vacation homes, were assumed to be available in all cases.

Establishment of these data bases on an SLA basis enabled an evaluation of probable shelter use. Limitations on distance of travel outside the resident SLA allowed excess spaces in nearby SLAs to be used by urban residents. Estimates were made on occupancy of home basements and NSS shelters with travel allowance of 0.5, 1.0, 2.0, and 5.0 miles (0.8, 1.6, 3.2, and 8.0 km). Spaces in NSS shelters were listed by eight average protection factors (PFs) ranging from 15 to 2000. Home basements were assumed to have an average PF of 25, and their occupancy was varied from 5 to 50 persons per basement. Preference for home basements or NSS shelters was also considered. Within each SLA, home basements could be filled first to a set percentage of the population or to their capacity. If the basement preference were 0%, NSS spaces were assigned first, beginning with those with the highest PF.

In all three variations of NSS shelter use, the population occupying NSS shelters varied less than 5% when the travel distance was changed from 1.0 to 5.0 miles (1.6 to 8.0 km), and more than two-thirds of the NSS spaces remained unused, indicating that most of the NSS spaces are not readily accessible to the residential population.

Use of home basements varied from 35 to 87% of the U.S. 1970 population, depending on the fraction of the population preferring NSS shelters and on the number of people per basement. Variation of the travel distance from 1.0 to 5.0 miles affected less than 2% of the U.S. population. Increasing the allowable basement occupancy from 5 to 50 persons per basement raised the national average number of occupants per basement from 3.5 to 4.8. This small change reflects the number of basements in rural homes which are not readily accessible to the urban residential population. About 10% of the U.S. population (in about 300 counties) will not have access to either NSS shelters or home basements, even if the maximum number sheltered per home basement is extended to 50.

The estimates of instrument requirements for shelter occupants, excluding special emergency personnel, were based on the shelter posture resulting from the blast risk and nonrisk delineation of the NSS spaces, with maximum utilization of the better NSS spaces (0% basement preference), and up to 50 occupants allowed per home basement. In this posture, 60% of the United States population was sheltered in home basements (PF = 25), with 31% in NSS shelters and 9% unsheltered (PF = 5), as may be determined from the detailed profile shown in Table 2.1 by adding percentages in the risk and nonrisk areas in the various categories.

Three basic approaches were taken, in which instruments were allocated as follows:

Allocation A. One RADEF shelter set (one high-range survey meter, two high-range dosimeters, one dosimeter charger) per occupied NSS shelter, regardless of size, and one set to home basement shelters shared with nonowners.

Allocation B. One RADEF shelter set per occupied NSS shelter with less than 100 occupants, plus one dosimeter per 50 additional occupants and one survey meter per 200 additional occupants, and one RADEF set per shared home basement shelter.

Allocation C. Dosimeters provided on the basis of organization of the shelter population into units averaging ten people, with one survey meter per 200 occupants.

Estimates for the total requirement of radiological instruments for each of the three allocations are summarized in Table 2.2.

Allocation A is the same as previous civil defense allocations, except that only NSS shelters expected to be occupied are assigned RADEF sets, and shared home basement shelters are also assigned RADEF sets. This instrumentation would provide dose records for only a very small fraction of the occupants in the approximately 65,000 shelters which

Table 2.1. Protection Factor Profiles in Risk[a] and Nonrisk Areas with Maximum Usage of NSS Shelters (BP = 0.0%) in 1.0-mile Travel Radius

	Risk Areas		Nonrisk Areas	
Average PF	Population (millions)	Percent of Total U.S. Population	Population (millions)	Percent of Total U.S. Population
5[b]	12.3	6.1	6.1	3.0
15	0.0	0.0	4.7	2.3
25[c]	82.1	41.0	37.1	18.5
30	0.0	0.0	5.8	2.9
70	12.1	6.0	12.2	6.1
125	5.3	2.6	4.3	2.1
200	2.5	1.3	1.6	0.8
375	2.6	1.3	1.4	0.7
750	1.6	0.8	0.7	0.4
2000[d]	5.6	2.8	2.6	1.3
Total	124.1	61.9	76.5	38.1

[a]Risk areas are those SLAs with geographical centroids which fall within the regions of 2 psi or greater overpressure from the hypothetical CRP-2B attack.

[b]Shelter in home with no basement, or unsheltered.

[c]Shelter in home basements with maximum occupancy of 50 per basement.

[d]Includes special facilities (mines, caves, tunnels, etc.).

Table 2.2. Estimated Total Requirements for Shelter Radiological Instruments

	Survey Meters (Millions)	Dosimeters (Millions)	Chargers (Millions)	Estimated Total Cost[a] (Millions of Dollars)
Allocation A - minimum (one RADEF set per occupied NSS shelter)[b]	1.2	2.4	1.2	60
Allocation B - minimum for radiological defense countermeasures[c]	1.4	3.4	1.3	75
Allocation C - minimum for radiological defense countermeasures and to provide dose records for each shelter occupant[d]	1.4	18.1	1.9	228

[a]Estimated cost per instrument: survey meter, $20; fiber-electroscope dosimeter, $10; charger, $10 (private communication, C. Siebentritt, 1978).

[b]Grossly inadequate for shelters with more than 200 occupants.

[c]Not adequate for maintaining dose records for each shelteree.

[d]Does not provide instrumentation for approximately 35 million home basement shelters used but not shared and approximately 18 million people without shelter under CSP.

would each contain more than 200 occupants, involving about 53 million people. Allocation B provides an estimated minimum requirement of instrumentation for countermeasures to radiation exposure, such as movement of shelterees and construction of expedient shielding. It would not be adequate for maintaining dose records for each shelteree. Allocation C would provide sufficient instrumentation for radiation countermeasures and also would enable a suitable dose record for each shelteree to be maintained. This record is important for the post-attack recovery period.

The instrumentation requirements listed in Table 2.2 do not take into account approximately 35 million home basements which are not shared, but serve as shelters for their usual occupants, and the approximately 18 million people for whom neither NSS shelter nor home basement shelter is available under the Community Shelter Program.

2.2 Recommendations

2.2.1 Additional shelter information.

Allocation C could be refined if the computerized data base on shelters included information on shelter configuration and variability of PF. For example, if a shelter has a highly variable PF from one location to another, the shelter unit should not have more than six or seven members. But if the PF is uniform throughout most of the shelter space, management could increase the number of people per shelter unit, possibly doubling it, with substantial reduction in instrument requirements and little change in the accuracy of individual dose records. Shelter configuration may also affect the size of the shelter unit. Shelters with many small rooms, or those consisting of long, narrow tunnels, would suggest the organization of small units (6 or 7 members). Information on shelter configuration and variability of PF would require a survey by local civil defense officials on a format readily adaptable for a computer data base.

Supplementary information, which would also be useful for refinement of allocation C, would be an estimate of the number of occupants expected to use a shelter and how many shelter units would be organized. This information would probably require more detailed planning than most local civil defense officials are prepared or willing to accomplish. Such planning could serve as a useful training exercise for local civil defense officials, possibly to prepare them better for implementation of the Community Shelter Program.

2.2.2 Shared home basement shelters.

Under the Community Shelter Program, one out of 35 homeowners with basements will be expected to share their basements as shelters. Almost 60% of the U.S. population may be sheltered in home basements. Many of the shared basements will be packed to maximum capacity, perhaps with 50 or more occupants. Several things need to be done in anticipation of heavy home basement use.

1. The ORNL shelter availability data base should be examined to pinpoint the SLAs in which basement sharing will be necessary to provide adequate shelter in CSP.

2. Additional shelter space should be sought in these SLAs. The ORNL data base should be updated as additional shelters are identified.

3. Special planning and preparation should be made for areas in which basement sharing will still be necessary after additional shelter has been sought. Local civil defense officials should be informed of the need to share basements and assisted in incorporating the shared basements into their plans. Steps should be taken to aid the homeowner and assist him or her with supplemental ventilation, sanitation, food, water, and help in organizing the additional occupants.

4. In the next federal census, the number of homes with basements should again be determined, with information as to whether or not the basement is belowground on all sides. A more detailed description will enable planners to determine how many basements may be suitable for fallout shelter, and for possible upgrading.

It would also be useful to find out whether the homeowner would be willing to share his basement in a life-or-death situation. This type of information may not be appropriate for a census and may require an independent survey. Such surveys have been conducted by DCPA on a limited basis in the past; they generally indicate that occupants would be willing to share.

2.2.3 Additional shelters.

Special efforts should be made to find additional shelters, properly located, to replace the very small public shelters (under 20-30 spaces) and to reduce the number of occupants in very large shelters (over 1000 spaces). It is costly to provide instruments, supplies, and trained management for small public shelters. A large shelter population may be extremely difficult to manage, but may be worth the additional effort in planning if the PF is high.

Additional shelters are also needed in about 300 counties where neither NSS shelters nor basements in homes provide enough spaces. In these areas, it may be possible to find shelter by allowing people to travel a greater distance.

The specific areas in which additional shelters are needed and the availability of shelter spaces at greater distances can be determined by examination of the ORNL shelter availability data base in conjunction with the ORNL shelter posture program.

2.2.4 Instruments.

An inexpensive, accurate, rugged, and reliable combination dosimeter-ratemeter remains a desirable goal. Development of such an instrument should have a higher priority than currently given. Until such instruments are available, the low-cost electroscope-type dosimeters and ratemeters now being developed are an important factor in radiological defense preparedness.

3. PARAMETERS AFFECTING REQUIREMENTS FOR RADIOLOGICAL INSTRUMENTS IN SHELTERS

3.1 Introduction

In order to estimate requirements for dosimeters and ratemeters, a systematic review was made of the parameters which affect the requirement for radiological instruments in shelters. After reviewing these parameters, it was apparent that the available data bases as described in Appendices D and E are inadequate for the preparation of estimates which incorporate all of these parameters or even some of the most important ones. In spite of this failing, preliminary and rough estimates of the instrument requirements for shelters, based on the available data, are made in Sect. 4. Additional data could be obtained from local civil defense directors which would enable a more precise estimate of instrument requirements to be made.

The problems involved in providing radiological instruments for individual citizens have been reviewed by a committee of the National Academy of Sciences, as reproduced in Appendices A and B. Their recommendations on the need for radiological instruments, desirable characteristics of the instruments, and how they should be used provide a useful basis for considerations made in this section.

The factors affecting instrument requirements are classified into four general categories: (1) instruments, (2) shelter occupants, (3) shelters and their environments, and (4) modes of shelter management, operation, and organization. The detailed parameters are listed in Table 3.1. Each of these parameters will be discussed briefly in terms of how they affect the requirements for instruments, their relative importance, and, where applicable, the feasibility of obtaining data concerning them. Many of the parameters are overlapping and interrelated.

3.2 Availability of Instruments

The number of pertinent DCPA radiological instruments on hand in the United States, as of November 1977, is listed in Table 3.2. The distribution of RADEF sets, dosimeters, and chargers as issued to the

Table 3.1. Parameters Affecting Radiological Instrument Requirements in Shelters

Parameter	Sufficient Data?	Comments
A. Instruments		
1. Instrument availability	Yes	
2. Instrument cost	Yes	May change because of new instrument developments
3. Instrument function	Yes	
4. Instrument reliability	No	New dosimeters are only in development stage
B. Occupants		
1. Number of occupants	No	Need firmer data on usage of basements
2. Characteristics of shelter occupants	No	
3. Vulnerability of occupants to radiation	No	
C. Shelter and Environment		
1. Shelter configuration	No	Data not processed for computer
2. Shelter size (number of spaces)	Yes	
3. Variations in PF within shelter	No	Data not processed for computer
4. Average PF of shelter	Yes	
5. Detailed analysis of shelter PF	No	

Table 3.1. (continued)

Parameter	Sufficient Data?	Comments
6. Fallout risk at shelter location	No	Depends on attack and on meteorological conditions at the time of attack
7. Communications with exterior world	No	
8. Effectiveness of local RADEF monitoring	No	
9. Decontamination capability	No	
D. Shelter Management, Operation, and Organization		
1. Number of people per shelter unit	No	Depends on number of occupants, shelter configuration, and variations of PF in shelter
2. Movement of occupants for life support, i.e., eating, sanitation supplies, etc.	No	
3. Movement of occupants for training and recreation	No	
4. Movement of occupants for RADEF	No	Depends on the variation of radiation intensity at different locations in the shelter
5. RADEF procedures in the shelter	No	

Table 3.2. Radiation Detection Instruments on Hand in the United States (figures rounded off)

Source: DCPA Plans and Operations (as of November 1977)

Instrument Type	Number	Approximate Cost per Instrument (1977 dollars)
Survey Meters		
CD V-715 - High Range 0-0.5 R/hr 0-5 R/hr 0-50 R/hr 0-500 R/hr	500,000	$ 60.00
CD V-717 - High Range Remote Reading *Detector remotable to 25'* Ranges same as CD V-715	100,000	100.00
CD V-720 - High Range with Beta Discriminator 0-5 R/hr 0-50 R/hr 0-500 R/hr	70,000	80.00
Total for High-Range Survey Meters	670,000	
High Range Dosimeters (Self-reading)		
CD V-730 0-20 R	130,000	20.00
CD V-740 0-100 R	120,000	20.00
CD V-742 0-200 R	2,650,000	20.00
Total for High-Range Dosimeters	2,900,000	
Chargers		
CD V-750 - For All Self-Reading Dosimeters	450,000	15.00

various states, as of March 1977, is shown in Table 3.3. The instruments included in Table 3.2 but not accounted for in Table 3.3 are located in state maintenance facilities, in a federal warehouse, and in various training programs throughout the states. Estimates on the number of new radiological instruments to be manufactured must take these existing instruments into consideration.

If large numbers of additional radiological instruments are manufactured for DCPA within the next few years, they will very likely be a mixture of several types being jointly developed by DCPA and the military services. One type is a fiber dosimeter based on the electroscope principle, identical in physical dimensions and operation to the CD V-742, but designed with improvements to be mass-produced by injection molding of special thermoplastics, thus reducing cost and improving reliability. The cost is anticipated to be about $10 each in mass production. Another type in development is a fiber-optics dosimeter which uses the darkening of special optical fibers on exposure to high energy photons (gamma rays) to measure radiation exposure. This design requires no electronics or precision components and should cost less than $3 each in mass production. A fiber-electroscope ratemeter is also in development for mass production by injection molding and should cost about $20 each. A piezoelectric charger for the electroscope-type radiation instruments is expected to cost about $10 each in mass production (Siebentritt, 1978).

According to a 1976 survey by Brashear (1977), five American companies produce commercially available dosimeters with alarms and digital readout; these are listed with summarized characteristics in Table 3.4. All of these instruments use a Geiger tube as the sensor, adding substantially to the cost and complexity of the electronic circuit. Because of their cost, this type of instrument would probably not be purchased by DCPA for general shelter use, although they could be useful under many circumstances. These dosimeters, with high sensitivity and 1 mR resolution, can also serve as accurate ratemeters when used with a wristwatch with a second hand. With modern integrated circuits it should be possible to redesign the digital dosimeter to display either accumulated dose or radiation rate by using a function switch.

Table 3.3. RADEF Sets and Emergency Worker Equipment Issued

Area	Shelter Monitoring Sets[a]	Monitoring and Reporting Sets[b]	Self-Protection Monitoring Sets[b]	Emergency Worker Dosimeters[c]	Emergency Worker Chargers
Total	140,029	51,814	28,861	1,150,216	74,725
Region 1	37,418	8,390	6,171	333,203	13,872
Connecticut	2,196	756	324	26,045	642
Maine	741	437	396	10,181	762
Massachusetts	3,846	851	686	32,699	1,294
New Hampshire	470	451	22	1,965	115
New Jersey	4,527	1,996	654	40,183	1,613
New York	22,074	3,153	887	187,950	7,377
Rhode Island	1,319	180	911	10,342	790
Vermont	314	128	64	254	167
Puerto Rico	1,916	431	2,227	22,984	1,032
Virgin Islands	15	7	0	600	80
Region 2	15,941	5,516	1,156	195,668	20,672
Delaware	504	149	163	6,066	266
Dist. of Columbia	710	15	53	10,000	500
Maryland	2,385	959	145	31,500	1,285
Pennsylvania	8,656	1,972	681	118,682	11,307
Virginia	2,738	1,648	114	7,770	3,681
West Virginia	948	773	0	21,650	3,633

Table 3.3. (continued)

Area	Shelter Monitoring Sets[a]	Monitoring and Reporting Sets[b]	Self-Protection Monitoring Sets[b]	Emergency Worker Dosimeters[c]	Emergency Worker Chargers
Region 3	16,992	6,137	7,078	133,976	7,390
Alabama	3,102	563	1,927	22,330	916
Florida	3,766	1,007	436	32,243	1,171
Georgia	2,190	884	3,063	9,191	1,596
Kentucky	1,501	927	282	8,899	461
Mississippi	703	1,401	23	21,731	1,662
North Carolina	2,740	746	172	11,180	458
South Carolina	1,021	250	710	13,102	536
Tennessee	1,969	329	465	15,300	590
Region 4	28,172	8,740	3,241	171,480	13,645
Illinois	5,487	1,253	642	14,628	6,921
Indiana	3,666	1,610	517	18,705	748
Michigan	4,749	1,759	668	50,843	2,136
Minnesota	5,541	1,215	309	23,318	1,503
Ohio	4,745	1,633	388	25,366	955
Wisconsin	3,684	1,270	717	38,620	1,382
Region 5	10,264	9,592	2,063	114,565	5,121
Arkansas	801	1,405	46	11,757	459
Louisiana	1,212	803	419	20,344	910
New Mexico	1,171	321	388	6,766	401
Oklahoma	1,964	2,123	641	12,819	966
Texas	5,116	4,940	569	62,879	2,385

Table 3.3. (continued)

Area	Shelter Monitoring Sets[a]	Monitoring and Reporting Sets[b]	Self-Protection Monitoring Sets[b]	Emergency Worker Dosimeters[c]	Emergency Worker Chargers
Region 6	16,915	6,509	4,505	109,324	7,626
Colorado	861	371	338	5,347	388
Iowa	2,694	880	835	24,982	2,402
Kansas	2,298	956	749	8,562	339
Missouri	3,673	1,156	245	42,726	3,111
Montana	910	224	764	3,380	133
Nebraska	1,873	1,010	225	15,233	891
North Dakota	933	250	810	2,984	135
South Dakota	1,382	474	408	1,525	0
Utah	1,324	735	0	1,377	27
Wyoming	967	453	131	3,208	100
Region 7	10,049	5,168	2,972	63,628	3,721
Arizona	777	460	270	4,406	362
California	8,053	3,719	2,531	53,488	2,437
Hawaii	406	274	118	3,300	66
Nevada	813	695	43	1,734	842
American Samoa	0	0	0	0	0
Guam	0	20	10	700	14
Region 8	4,278	1,762	1,675	28,372	2,678
Alaska	130	80	63	240	124
Idaho	571	338	433	2,353	299

Table 3.3. (continued)

Area	Shelter Monitoring Sets[a]	Monitoring and Reporting Sets[b]	Self-Protection Monitoring Sets[b]	Emergency Worker Dosimeters[c]	Emergency Worker Chargers
Oregon	1,406	814	705	13,348	1,336
Washington	2,171	530	474	12,431	919

Source: Program Status Report, March 1977, total of state level and local level radiological instruments, DCPA, Plans and Operations.

[a]Contains 2 high-range dosimeters, 1 charger, and 1 high-range survey meter.

[b]Contains 2 high-range dosimeters, 1 charger, 2 high-range survey meters, and 1 low-range survey meter.

[c]High-range

Table 3.4. Dosimeter Comparison (1976)

(Courtesy of H. R. Brashear, 1977)

Company	Model	1 Off-the Shelf Item-"X"; Will Modify If Ordered In Quantity-"M"; Has Options-"O"	2 Size	3 Push Button Readout Directly In Milliroentgens	3a Dose Reset	4 Chirp or Beep With Dose Accumulation Internally Selectable-"S"; Not Selectable-"N"	5 Continuous Alarm, Selectable Alarm Point, Internal-"I"; External-"E"; Not Selectable-"N"	5a Dose Accumulation Regardless Of Alarm Condition	6 Audible Detector Saturation Alarm	7 Rugged and Shock Resistant As Per Manufacturers Statement	8 Nominal Battery Life, (Hours) Type of Battery	9 Dose Accumulation Range, (Mr) Overflow Indication	10 Dose Memory Protect	11 Stated Accuracy	12 Dose-Rate Range	13 Base Price/With Options, $
Victoreen	885	July 76	2½×4½×1 6 Oz.	Yes LED	Guarded[1] External	Each Mr N	Yes-E	Yes	Yes	Yes	288	0-999 No	Optional	±20% 50-1000 KeV	To 7 R/Hr[6]	150/225
Technical Associates	PDR 1a	X	2¼×⅞×4¼ 5 Oz.	Yes[2] LED	External[3]	Each Mr N	Yes-E[3]	Yes[4]	Up To 300 R/Hr	Yes	3000 3 AAA	0-9999 No	Yes	±20% 60-1200 KeV	To 20 R/Hr	225
Eberline	Primadose	X	3.6×2.5× 0.84 4 Oz.	No Remote Reader	External + On-Off	Each 1.5 Mr N	Yes-E	Yes	Up To 500 R/Hr	Yes	1000 9 Volt	0-800 No	No	±20% 80-1200 KeV	To 30 R/Hr	225/395
Eberline	Prima Y	X	2¼×3½×1 0.6 Oz.	Yes LED	External	None	None	NA	No	Yes	400 9 Volt	0-999 No	No	±15% 80-1200 KeV	To 2 R/Hr	248
Reactor Experiments	Digi/Dose Alarm	X	2¾×4¼ ×4½ 10 Oz.	Electro-Mechanical Register	External	Each Mr N	Yes-I	Yes	No	Yes	300 9 Volt	0-9999 No	Yes	±15% 50-2000 KeV	Not Stated	295
Xetex, Inc.	Mini-Gard	X	1.9×2.5×1 3 Oz.	No Remote Reader	Internal	Each Mr N	Yes-I	Yes	No	Yes	Recharge-able	0-4096 No	No	±15% 70-1300 KeV	To 30 R/Hr	160
Wallac Oy (Finland)	RAD-21	X	2.9×5.3 ×8.7 7.4 Oz.	Yes LED	Guarded[1] External	6	Yes-I	Yes	Yes	Yes	200 Recharge-able	0-9999 No	Yes	±20% 50-3000 KeV	Not Stated	395

[1] External reset requires small tool
[2] A 10 second automatic readout with each chirp
[3] Controls external; looks like a cover could be installed
[4] Output latched at alarm point until alarm cleared, then true accumulated dose is displayed
[5] Optional G-M Tube for higher dose rate range
[6] Six selectable dose-rate alarm levels

The dose accumulation range would need to be extended by a factor of 10 or 20 for use in a nuclear fallout situation (see Table 3.4).

Within the next ten years a wristwatch digital dosimeter-ratemeter may become available through the development of crystal radiation detectors, such as the cadmium-telluride crystal. These instruments could be expected to be rugged, reliable, accurate, and sensitive and, in mass production, could possibly retail under $20 each. They would not be candidates for replacing the fiber-optics dosimeter, but could possibly replace and supplement the current survey meters, such as the V-715.

3.3 Cost of Instruments

If a reliable, rugged, and sufficiently accurate dosimeter could be mass-produced very cheaply, for example, at 10¢ each, the federal government might well consider stockpiling one instrument per individual, for issue in time of emergency. On the other hand, if the cheapest acceptable dosimeter costs over, say, $15 each, then the federal requirements for dosimeters would have to be analyzed much more carefully. These considerations suggest a listing of various bases for federal requirements of dosimeters based on hypothetical ranges of costs for dosimeters, as shown in Table 3.5. At present, it does not seem feasible to develop an acceptable dosimeter in the low cost range shown in Table 3.5. The fiber-optics dosimeter may be manufactured to sell in the medium cost range. Commercially available digital dosimeters are in the high price range, as shown in the last column of Table 3.4.

The listing in Table 3.5 is based on the simplifying hypothesis that only a single-type dosimeter would be considered. In actuality a mixture of different types of dosimeters may be more effective. For example, in a shelter with very poor lighting, a digital dosimeter with LED readout would be much easier to read than a fiber-electroscope dosimeter; the fiber-optics dosimeter may not be readable at all in such a shelter, unless a source of light such as a flashlight is available.

The costs of an injection-molded thermoplastic electroscope-type dosimeter and ratemeter and a piezoelectric charger were mentioned in Subsect. 3.2. Recapitulating, in mass production these costs are expected to be $20 each for the ratemeter, $10 each for the dosimeter and $10

Table 3.5. Hypothetical Cost Bases for Federal Requirements of Dosimeters for Issue in Time of Emergency

Hypothetical Cost Range of Dosimeter		Basis of Dosimeter Assignment	Number of Dosimeters (millions)	Total Cost Range (millions of dollars)
10-29¢	(low cost)	Each individual	214.6[a]	$ 21-105
30¢-$2.49		Each household head	72.9[b]	22-182
$2.50-$7.49	(medium cost)	Each household head (every third person) using national shelter and shared home basement shelters	33[c]	82-250
$7.50-$15		Each shelter unit leader (10 people per unit)[d] per national shelter and shared home basement shelter	18[c]	218-435
Over $15	(high cost)	Per analysis of individual shelter	?	?

[a] U.S. population, 1976, U.S. Bureau of the Census.

[b] Number of household heads (U.S. Bureau of the Census, Current Population Reports, Series P-20, No. 311, "Household and Family Characteristics: March 1976," U.S. Government Printing Office, Washington, D.C., 1977).

[c] Based on the risk and no-risk shelter postures described in Appendix E.

[d] Discussed in Sect. 4.

each for the charger. These estimates will be used in Sect. 4 to estimate costs of different allocations of instruments.

3.4 Function of Instruments

If an instrument can function both as a dosimeter and a ratemeter, then the total number of instruments required will be less. Because such instruments are likely to be expensive (see Table 3.4), they will not be considered for this program.

3.5 Reliability of Instruments

An extensive evaluation of the reliability of dosimeters has not been made, and it is not within the scope of this project to make such an evaluation. However, we note that it has become common practice for radiation-monitoring personnel to carry two dosimeters per person or per small group working together when they must enter radiologically contaminated areas. We recommend that a similar philosophy be applied in fallout shelters and in areas subjected to fallout. We recommend that a minimum of two dosimeters be assigned to each occupied shelter or to each isolated group in a potentially hazardous area. If one instrument should fail, be damaged, or lost, the occupants would then continue to have some means for indication of their radiation exposure. This philosophy has been incorporated in our estimates for requirements for dosimeters (e.g., Subsect. 3.17).

3.6 Number of Occupants Per Shelter (Shelter Posture)

This parameter is one of the most important ones in evaluating requirements for instruments, and estimates on the number of people per shelter are described in Appendix E. There we show that the shelter posture is most strongly affected by changes in the assumed fraction of the population preferring home basement shelters to national shelters and by how many people are assumed to be shelterable per basement.

When we assumed that people would prefer NSS shelters (0.0% basement preference) and all NSS shelters were allowed for sheltering within the 1- and 5-mile restrictions as described in Appendix E, we found that over 20,000 facilities would have over 1000 occupants each, averaging over 3000 occupants per facility (see Tables E.4 and E.5), and almost 50,000 facilities would have less than 50 occupants each.

When the NSS shelter data base was modified in the risk area (see Appendix D, Subsect. D.2.4 and D.5), the total number of facilities with over 1000 occupants each was reduced to 13,213; but the number with less than 50 occupants each increased to 78,345, as shown in Table 3.6. This table will be used in the estimation of instrument requirements in Sect. 4.

3.7 Characteristics of Shelter Occupants

In some shelters there may be concentrations of occupants with special skills who may be required to perform emergency services, such as policemen, firemen, doctors, nurses, maintenance and utilities workers, etc. These people will (or should) be supplied with radiological instruments giving them the capability for radiological self-protection; that is, they will need dosimeters to monitor their own exposures if they are required to leave the shelters for emergency services while the radiation fields remain potentially hazardous. A number of instruments have been distributed for this purpose, as shown in Table 3.3.

In such a shelter where there are many emergency workers, those additional instruments assigned to emergency workers could be used to supplement the estimates of exposure dose by a method suggested by Gupton (1977). During the early period of shelter confinement, dosimeters could be located around the shelter in fixed locations, mounted on walls, posts, etc., and the dose at each location would be read periodically. When the emergency workers must leave the shelter, they would take some of the dosimeters from the fixed locations, but a few would be left in place. The doses at the locations where the dosimeters were removed could then be calculated relative to the doses recorded at the locations where the dosimeters remain in place. The positioning and reading of dosimeters in shelters is discussed in the Handbook for Radiological Monitors (Department of Defense, 1963).

Table 3.6. NSS Shelter Occupancy in Risk and Nonrisk Areas with 1.0-mile Travel Radius

Number of Occupants per Shelter	Number of Shelters Occupied	Percent of Total Occupied Shelters	Number of Spaces Occupied	Percent of Total Occupied Spaces	Average Number of Occupants per Shelter
Risk Areas[a]					
1-19	25,263	20.0	349,398	1.2	13.8
20-49	28,816	22.9	962,805	3.2	33.4
50-99	21,659	17.2	1,557,702	5.2	71.9
100-199	18,294	14.5	2,659,605	9.0	145.4
200-499	18,438	14.6	5,891,939	19.9	319.6
500-999	8,131	6.5	5,657,462	19.1	695.8
1000+	5,381	4.3	12,571,413	42.4	2336.3
Subtotal	125,982	100.0	29,650,324	100.0	235.4
Nonrisk Areas					
1-19	9,492	10.9	131,067	0.4	13.8
20-49	14,774	17.0	525,846	1.6	35.6
50-99	14,798	17.1	1,100,977	3.3	74.4
100-199	14,588	16.8	2,141,024	6.5	146.8
200-499	16,962	19.5	5,460,296	16.4	321.9
500-999	8,348	9.6	5,897,139	17.7	706.4
1000+	7,832	9.0	17,992,668	54.1	2297.3
Subtotal	86,794	100.0	33,249,017	100.0	383.1
Total	212,776		62,899,341		295.6

[a]Risk areas are those SLAs with geographical centroids which fall within the regions of 2 psi or greater overpressure from the hypothetical CRP-2B attack.

3.8 Vulnerability of Shelter Occupants

Some shelters may have a greater than average concentration of children, old and/or sick people, or pregnant women. In these populations the tolerance to radiation may be less than average, or the potential for genetic damage greater. Such shelters should probably be provided with more instruments per occupant than the average shelter, to provide for greater frequency of readings and more accuracy in the record of individual dose. We have no data on how these more vulnerable occupants may be distributed, but the effect on the overall number of radiation instruments required is probably negligible. Data for estimation of this parameter could be obtained by a survey of local civil defense officials.

3.9 Shelter Configuration and Size

A shelter may consist of many individual rooms inside a large building, distributed over several stories, or it may be a single large room, a home basement, or a long tunnel or mine. In shelters with many individual rooms, it may be desirable to provide dosimeters for each room, particularly if there is a variation in PF between rooms. If a room has a fairly uniform PF throughout, a few dosimeters fixed in place will be adequate for the room, even though there may be a large number of occupants. These could be posted on the walls or other supports in convenient locations where an exposure indicated by the instrument would most closely represent the exposure of the occupants. Positioning of dosimeters is also discussed in the *Handbook for Radiological Monitors*, (Department of Defense, 1963).

In shelters consisting of single large rooms such as gymnasiums, auditoriums, or large, undivided home basements, with variable PF throughout the area, dosimeters should be provided for each shelter unit leader (7 to 12 persons per unit) as described in Subsect. 3.17. Additional dosimeters should be available for those who must temporarily leave the proximity of their unit.

In long tunnels, deep mines, or caves, the PF will be so high that no dosimeters would be required for a majority of the occupants while they remain in the shelter. For example, it requires only 6 ft of rock overhead to provide a protection factor of one billion in a cave, provided there are no leaks from the cave entrance. Low-level ratemeters should be on hand to detect contamination of the areas with high PF. The number of dosimeters for such facilities would be determined predominantly by the number of dosimeters required for emergency and recovery operations outside the shelter. For tunnels or mines, where there may be only one or two entrances for a very large space, the number of ratemeters would be based upon their need for emergency and recovery operations after the primary shelter period.

In the NSS summary file, which we obtained from the DCPA computer center, copied from their data as of December 1976, there are approximately 50,000 facilities with less than 20 spaces and 220 facilities with more than 50,000 spaces each. The average number of spaces per shelter is 819. If the facilities with less than 5 spaces are deleted from the NSS, the average number of spaces per shelter rises to 855, and if those with less than 50 spaces are deleted, the average rises to 1160. These averages are considerably higher than those we obtain (Tables E.4 and E.5) for the average number of occupants per occupied shelter, 565 and 620 for 1- and 5-mile radii respectively. These differences arise from two possibilities: (1) a number of the largest shelters are not used because they are not located where the population resides, and (2) a number of shelters will have more available spaces than the number of occupants available to fill them within the range of travel distance allowed.

If the January 1965 federal guidelines for stocking shelters remain in effect, then we need not consider requirements for shelters with less than 50 spaces. However, our shelter posture studies indicate that 37% of the 213,000 NSS shelters used in the risk-nonrisk posture will have less than 50 occupied spaces (see Table 3.6).

These considerations indicate that the requirements for radiological instruments may vary greatly from one shelter to another, depending on individual shelter configurations and sizes. Data are not available in computer format for evaluating the effect of configuration on the requirements for radiological instruments.

3.10 Variations in PF within Shelters

As noted above, shelters with fairly uniform PF over their area will require fewer dosimeters than those in which the PF differs from one location to another. In shelters in which radiation intensity is higher in some locations than others, due to nonuniform PF in the shelter, shelter managers may rotate the location of shelterees, by shelter units (7-12 people) if possible, to equalize exposure of all shelterees, as discussed in Subsect. 3.20. Dosimeters may be fixed in place in each PF area, and the exposure of each unit may be calculated from the period of time spent in each location.

3.11 Average PF of Shelter

Shelters with a very high average PF, such as caves, mines, and tunnels, may be operated with relatively few dosimeters for a large number of people, as noted previously. Those with a low average PF should have a higher ratio of dosimeters per person, particularly if the shelter is located in a high-fallout-risk area. The additional instruments are required to provide more accurate dose estimation for each individual, for two reasons: (1) to enable remedial action to be taken if it appears that the dose may approach or exceed the level for radiation sickness, and (2) to assess more precisely the initial time at which individuals may emerge from the shelters and the length of time they may remain out of the shelters.

The average PFs for the sheltered population in the CSP mode is shown in Table 3.7. These numbers were determined by procedures described in Appendices D and E. Ten categories of PF are listed; PF 5 corresponds to homes without basements and PF 25 to those with basements. About 74% of the U.S. population would have shelters of PF 30 or less. Because this large fraction of the U.S. population has relatively low radiation protection, no differentiation was made between shelters of low and high PF in the final allocation of instruments.

Table 3.7. Protection Factor Profiles in Risk[a] and Nonrisk Areas with Maximum Usage of NSS Shelters (BP = 0.0%) in 1.0-mile Travel Radius

	Risk Areas		Nonrisk Areas	
Average PF	Population (millions)	Percent of Total U.S. Population	Population (millions)	Percent of Total U.S. Population
5[b]	12.3	6.1	6.1	3.0
15	0.0	0.0	4.7	2.3
25[c]	82.1	41.0	37.1	18.5
30	0.0	0.0	5.8	2.9
70	12.1	6.0	12.2	6.1
125	5.3	2.6	4.3	2.1
200	2.5	1.3	1.6	0.8
375	2.6	1.3	1.4	0.7
750	1.6	0.8	0.7	0.4
2000[d]	5.6	2.8	2.6	1.3
Total	124.1	61.9	76.5	38.1

[a]Risk areas are those SLAs with geographical centroids which fall within the regions of 2 psi or greater overpressure from the hypothetical CRP-2B attack.

[b]Shelter in home with no basement, or unsheltered.

[c]Shelter in home basements with maximum occupancy of 50 per basement.

[d]Includes special facilities (mines, caves, tunnels, etc.).

3.12 Detailed Analysis of Shelter PF

If the radioactive fallout were deposited in a predictable manner and remained in place after deposition on the shelter exterior and surroundings, it would be theoretically possible to analyze the PF at every possible location of a shelteree. The requirements for dosimeters during the shelter period could then be reduced to only two for the entire shelter, even in those shelters where the total exposure may become significant. These dosimeters could be fixed in one location. Doses at other locations could be calculated by knowing the relative PFs. If there were a significant difference in PF from one location to another, estimated doses for each individual would require that a record be maintained of their movements throughout the shelter. The number of dosimeters in a shelter would then be dependent on the characteristics of the shelter occupants, that is, on how many self-protection sets have been issued for emergency workers in the shelter.

Unfortunately, the deposition of fallout on and around the shelter may be uneven, and wind and rain will cause the fallout to accumulate in corners, eaves, troughs, etc. The dose calculated from a theoretical fallout distribution and an analytical evaluation of PF may be disastrously misleading in some shelters. For these reasons, this method of estimating dose is not generally recommended, although it might be necessary in emergency situations where there are insufficient instruments on hand.

3.13 Fallout Risk at Shelter Location

An examination of High Risk Areas (Department of Defense, 1975b) shows that most of the area of the United States is not considered a high risk for fallout. A more specific analysis (Haaland et al., 1976) demonstrates that the same CRP-2B attack could produce fallout lethal to over half the unsheltered people in 60% of the area of the coterminous United States. One might assign more dosimeters per person in the high-fallout-risk areas than in the low-fallout-risk areas. The risk areas, however, are determined only by a probability analysis. In an actual situation, a whim or error on the part of the attacker, a malfunction in the weapon delivery system, or a change in meteorological conditions may subject a "low-risk" area to lethal radiation. Because of these uncertainties, the entire population should be provided with the minimum number of dosimeters needed to provide a reasonable estimation of their radiation exposure, regardless of their estimated fallout risk.

This parameter will not be considered as a factor in our estimates for instrument requirements.

3.14 Communications with Exterior World

If as a result of remoteness or because of the attack (e.g., EMP effects) a shelter has little or no means of outside communication, such as radio, TV, or telephone, a higher ratio of dosimeters per person may be desired by the shelter administration and by the shelterees to assure everyone that their radiation exposure is being properly monitored. On the other hand, if the shelter has excellent communications with the local EOC and broadcasting stations, the ratio of dosimeters per person may possibly be reduced without apprehension. A minimum number of radiological instruments must, nevertheless, be retained in the shelter regardless of the status of the communications system.

This parameter is considered to be of secondary significance and will not affect our estimate of instrument requirements.

3.15 Effectiveness of Local RADEF Monitoring

If the local RADEF monitoring capability is ineffective, additional ratemeters and dosimeters may be needed in the shelter during the emergent period. Additional dosimeters may also be desirable during the shelter confinement period to provide additional assurance that dose is being effectively monitored.

On the other hand, if there were an effective RADEF monitoring capability in the general area of the shelter, and good communications to and from the shelter with the local EOC, fewer dosimeters and ratemeters may be required for the emerging stage if the radiation fields have been mapped thoroughly in the vicinity of the shelter.

This parameter is also considered to be of second-order significance because it primarily affects the emerging stage. It will not affect our estimate of instrument requirements.

3.16 Decontamination Capability

In some unusual shelters, such as in a ship on a large lake or at sea, or in a shelter below a large expanse of paved surface, or in a high-rise building, it may be possible to decontaminate the fallout-collecting surfaces by various automatic or remotely operated devices to the extent that the radiation intensity in the shelter and vicinity is negligible. In such cases the requirements for radiological instruments will be much less than in most other shelters. Because the number of shelters with this special capability is expected to be very small, this parameter will not be considered in our estimate of instrument requirements.

3.17 Number of People per Shelter Unit

According to the Shelter Management Textbook (Department of Defense, 1967), shelter units may vary in size from 7 to 12 members. The chosen unit size will depend on the total number of occupants in the shelter, the shelter configuration, relationships of occupants to each other, facilities and supplies in the shelter, and the availability of trained shelter managers.

If there is significant variation in radiation intensity from one location in the shelter to another, the people in a unit may be required to move from one location to another as a unit. Monitoring and recording of the dose should be carried out for each unit. In shelters with less than, say, five units, there should be two dosimeters for each unit, so that if one dosimeter is lost or malfunctions, the dose for the unit will continue to be monitored by the remaining instrument. If that instrument is lost or malfunctions, the remaining dosimeters in the shelter may be redistributed or the shelter units reorganized. If the shelter has more than five units, it may be possible to maintain a record of dose sufficiently accurately with only one dosimeter per unit. In this case, if the dosimeter is lost or damaged, the dose for that unit may be estimated by the dose of another unit which has had similar movements through the shelter.

From these considerations, a tentative allocation of dosimeters for occupants in shelters with significant variation in PF from one location to another can be constructed as shown in Table 3.8. Dosimeters for

Table 3.8. A Possible Allocation of Dosimeters to Shelters, Based on Number of Shelter Units, for Shelters with Significant Variation in PF from One Location to Another

Number of Shelter Units	Number of Dosimeters in Use by Units	Number of Dosimeters for Shelter Management above Unit Leaders	Total Number of Dosimeters per Shelter	Ratio of Dosimeters/Person (10 People/Unit)
1	2	0	2	0.20
2	4	0	4	0.20
3	6	0	6	0.20
4	8	0	8	0.20
5	5	1 (Shelter Mgr.)	6	0.12
6	6	1	7	0.12
7	7	2 (Add Deputy)	9	0.13
8	8	2	10	0.12
9	9	2	11	0.12
10	10	2 (Add 2 Section Heads)[a]	12	0.12
15	15	2 (Add 1 Section Head)	17	0.11
20	20	4 (Add 1 Section Head and 2 Division Heads)	24	0.12
30	30	4 (Add 2 Section Heads)	34	0.11
50	50	4 (Add 4 Section Heads)	34	0.11

Table 3.8. (continued)

Number of Shelter Units	Number of Dosimeters in Use by Units	Number of Dosimeters for Shelter Management above Unit Leaders	Total Number of Dosimeters per Shelter	Ratio of Dosimeters/Person (10 People/Unit)
75	75	5 (Add 5 Section Heads and 1 Division Head)	80	0.11
100	100	6 (Add 5 Section Heads and 1 Division Head)	106	0.11
200	200	12 (Add 20 Sections Heads, 4 Division Heads, and 2 Department Heads)	212	0.11
300	300	17 (Add 20 Section Heads, 4 Division Heads, and 1 Department Head)	317	0.11

[a] Dosimeters not provided to Section Heads.

shelter management are shown in separate columns from those intended for use by shelter units. The ratio of dosimeters per person ranges from 0.2 (1 per 5 people) in the smallest shelters to 0.11 (1 per 9 people) in the largest, based on an average of 10 people per shelter unit. Instruments for emergency workers are not included in these tables.

The number of people per shelter unit may be selected to provide maximum control of radiation exposure. In shelters with great variation in PF or with potentially hazardous radiation intensities, it may be desirable to reduce the size of the shelter units, thus providing both a higher ratio of dosimeters per person and a greater number of managers to control the exposure to radiation.

Some examples of possible breakdowns of shelter population into units are shown in Table 3.9. In a situation where the radiation intensity is not hazardous or highly variable throughout the shelter, a shelter with 40 people could be divided into only three units, with six dosimeters according to Table 3.8. On the other hand, if the radiation intensity is potentially hazardous in some locations of the shelter, it may be more desirable to divide the 40 people into as many as 8 units, with 10 dosimeters and one shelter manager and one deputy shelter manager. In this approach to the organization of shelter units, the size of the unit has been varied from 4 to 14 people, instead of from 7 to 12 as indicated in the Shelter Management Textbook (Department of Defense, 1967).

The number of people per shelter unit is one of the parameters used in estimating radiological instrument requirements. An average of ten people per unit was used in the estimate made in Sect. 4.

3.18 Movement of Occupants for Life Support

If a shelter has uniform radiation intensity throughout the habitable space, the movement of the occupants will not require any additional instrumentation for monitoring dose. In many shelters there will be a significant variation of radiation intensity from one location to another, perhaps sometimes as much as by factors of hundreds. In such shelters the movement of occupants must be curtailed or controlled. If there must be movement through areas of higher radiation intensity, the

Table 3.9. Dosimeter Requirements Based on Number of People per Shelter Unit

Number of People in Shelter	Number of Shelter Units	Number and Size of Units	Required Number of Dosimeters (Based on Table 3.8)	Ratio of Dosimeters per Person
5	1	1-5[a]	2	0.4
10	1	1-10	2	0.2
	2	2-5	4	0.4
20	2	2-10	4	0.2
	3	1-6, 2-7	6	0.3
	4	4-5	8	0.4
40	3	2-13, 1-14	6	0.15
	4	4-10	8	0.2
	5	1-7, 4-8, 1 mgr.	6	0.15
	6	1-5, 2-6, 3-7, 1 mgr.	7	0.18
	7	5-5, 1-6, 1-7, 2 mgrs.	9	0.225
	8	2-4, 6-5, 2 mgrs.	10	0.25

[a]"1-5" means one unit with five people.

doses should be monitored. Whenever possible, the designation of areas for eating and drinking and for personal hygiene and sanitation should be made to reduce overall exposure to radiation. The shelter manager may consider the alternatives of whether food and water should be brought to the occupants, or whether the occupants should move to a serving area. In general, movement of occupants in a shelter will depend on the shelter size and configuration and the availability and location of facilities for life support.

The primary factor here is the variability of radiation intensity in the shelter; hence this parameter of movement is considered to be of secondary importance and will not affect our allocation of radiological instruments.

3.19 Movement of Occupants for Training and Recreation

Such movements may be possible only in shelters which are partially filled, as may be the case in many urban areas where the number of available shelter spaces may far exceed the number of people living within a 1- or 2-mile radius. If purely recreational movements involve a strong risk of increased radiation exposure, then it would seem in most cases more reasonable not to make the movements rather than to require additional instruments to monitor the possible increased radiation. Movements for training may be made on the judgement of the shelter management. Requirements for instruments for these purposes will not influence our estimates.

3.20 Movement of Occupants for Exposure Control

In some shelters the variations in radiation intensity may require that shelter units rotate their locations with other units periodically to share the radiation exposure evenly. If such movement becomes necessary, as determined by measurements with ratemeters at various locations in the shelter, the shelter manager should very carefully plan where people should move, based on rate measurement, and when people should move, based on exposure measurements. Shelter management should explain to the shelterees the reasons for such movements. An open and honest approach usually results in better cooperation from the public than one in which the public is uninformed and may suspect deception. Because the radiation decays with time as $t^{-1.2}$ and will be the most intense during the first hours after the fallout arrives, the need for rotation of locations will be the strongest during the first day or two of shelter occupancy. This need for early movement may conflict with the need for organizing the shelter. Local civil defense officials should become familiar with the shelters in their jurisdiction so they can become aware of those shelters which may pose this problem. If possible, plans for assignment of instruments and unit movements during the first few days of occupancy of these shelters should be made in advance. The initial organization may be a temporary one.

In some respects, the need to rotate the location of shelter units may be beneficial to the morale of the occupants, because the necessary activity of assembling their personal belongings and cleaning up their area to make it habitable for the next unit will provide a distraction and occupy their time.

3.21 RADEF Procedures in the Shelter

Each ratemeter will usually be assigned to a radiological monitoring team, who will monitor radiation in the shelter around the clock, as specified and discussed in the Shelter Management Textbook (Department of Defense, 1967) and in the Handbook for Radiological Monitors (Department of Defense, 1963).

Dosimeters may be deployed in one of three general ways: (1) they may be assigned to shelter unit leaders, (2) they may be posted at fixed locations on walls or posts, and (3) they may be issued only to members of radiological monitoring teams, independent of shelter units, who are dispersed throughout the shelter. Selection of the means of deployment will depend on the shelter size, configuration, variability of PF, etc., as discussed above.

3.22 Conclusion

Numerous factors enter into the considerations or requirements for radiological instruments in shelters. Data on many of these factors, such as shelter configuration, variability of PF within the shelter, and the planned organization of occupants within the shelter, do not exist at the federal level. The ultimate determination of the number of instruments required will depend on detailed assessments made by local civil defense officials.

4. ESTIMATION OF THE NUMBER OF RADIOLOGICAL INSTRUMENTS REQUIRED FOR SHELTERS

4.1 Introduction

Estimates are given for the number of radiological instruments required for shelter occupants, including shelter management. These numbers exclude instruments required for emergency workers and post-attack recovery operations. The minimum number of instruments required is given under each of the three following allocations:

Allocation A. A minimum number of instruments for survival is estimated, to be supplemented by instruments already provided to emergency workers.

Allocation B. A minimum number of instruments for survival is estimated, independent of the number of instruments provided to emergency workers.

Allocation C. A minimum number of instruments is estimated to minimize radiation exposure and to provide a record of dose for each individual.

4.2 Minimum Number with Supplementary Instruments (Allocation A)

In this case, one RADEF set or equivalent (one survey meter, two dosimeters, and a charger, if required by the dosimeters) is assumed to be supplied to each occupied NSS shelter, regardless of size, and one to each home basement in which shelter space is shared. This allocation may be compared with that of the Federal Civil Defense Guide, Part D, Chap. 2, Appendix 1 (Department of Defense, 1965), in which one "shelter radiation kit" (RADEF set) is supplied per shelter of 50-1000 spaces.

In the shelters with many occupants, where more than one instrument set would be needed, it is assumed that additional dosimeters and rate-meters will become available during the shelter confinement period from those issued to emergency workers.

From Table 3.6, there are 126,000 occupied NSS shelters in risk areas and 87,000 in nonrisk areas, making a total of 213,000 occupied shelters. From Appendix C, the estimated number of shared home basement shelters is one million. Hence 1.2 million RADEF sets would be required with this dispersal formula. This requirement consists of 1.2 million survey meters, 2.4 million dosimeters, and 1.2 million chargers, if the fiber-electroscope type of dosimeter is used.

The total cost for this instrumentation would be about $60 million, using costs from Subsect. 3.3, with the breakdown given in Table 4.1.

Table 4.1. Minimum Instrument Requirements for Shelters, when Supplemented by Emergency Workers' Instrumnets (Allocation A)

Instruments	Estimated Requirement (million $)	Estimated Cost per Instrument ($)	Total Estimated (million $)
Survey meters	1.2	20	24
Dosimeters	2.4	10	24
Chargers[a]	1.2	10	12

[a]Fiber-optics dosimeters would not require chargers.

In large shelters this allocation of radiological instruments may lead to problems, such as the following:

1. Many large shelters may not have emergency workers assigned to them, and no supplemental instrumentation would be available. The number of instruments in shelters with 100 or more occupants (about 100,000 shelters, see Table 3.6) would be grossly inadequate, especially in shelters with large differences in PF from one location to another.

2. Discipline and morale problems may arise when emergency workers remove radiological instruments from the shelters to perform their operations.

3. Emergency workers may not wish to relinquish for general use the instruments assigned to them for self protection.

4. In all shelters except those of highest and most uniform PF and those in the smallest category, it will be impossible to guarantee equal radiation exposure or to provide a record of dose for any except a very small fraction of the sheltered population.

For these reasons a more generous allocation of instruments is recommended.

4.3 Minimum Number Independent of Supplementary Instruments (Allocation B)

In this case, one RADEF set is allocated for each shelter with less than 100 occupants, one dosimeter is provided per 50 additional occupants, and one survey meter is provided per 200 additional occupants. Chargers are allocated at one per shelter for shelters with less than 500 occupants, and at one charger per approximately eight dosimeters for larger shelters. This allocation, applied to the shelter occupancy as given in Table 3.6, results in a requirement of 1.4 million dosimeters, 0.3 million chargers, and 0.4 million survey meters for occupants of NSS shelters (see Table 4.2). The requirement of one RADEF set per shared home basement is added to

Table 4.2. Allocation of Minimum Instrumentation for Shelters, without Supplementary Instrumentation

Occupants per Shelter	Number of Shelters Occupied	Average Number of Occupants per Shelter	Allocated per Shelter[a]			Total Allocated (millions)		
			Dosimeters	Chargers	Survey Meters	Dosimeters	Chargers	Survey Meters
Risk Areas								
1-19	25,263	14	2	1	1	0.051	0.025	0.025
20-49	28,816	33	2	1	1	0.058	0.029	0.029
50-99	21,659	72	2	1	1	0.043	0.022	0.022
100-199	18,294	145	3	1	1	0.055	0.018	0.018
200-499	18,438	320	6	1	2	0.111	0.018	0.037
500-999	8,131	696	14	2	3	0.114	0.016	0.024
1000+	5,381	2336	47	5	12	0.253	0.027	0.065
Total						0.685	0.155	0.220
Nonrisk Areas								
1-19	9,492	14	2	1	1	0.019	0.009	0.009
20-49	14,774	36	2	1	1	0.030	0.015	0.015
50-99	14,798	74	2	1	1	0.030	0.015	0.015
100-199	14,588	147	3	1	1	0.044	0.015	0.015

Table 4.2. (continued)

Occupants per Shelter	Number of Shelters Occupied	Average Number of Occupants per Shelter	Allocated per Shelter[a]			Total Allocated (millions)		
			Dosimeters	Chargers	Survey Meters	Dosimeters	Chargers	Survey Meters
200-499	16,962	322	6	1	2	0.102	0.017	0.034
500-999	8,348	706	14	2	3	0.117	0.017	0.025
1000+	7,832	2297	46	5	11	0.360	0.039	0.086
Total						0.702	0.127	0.199
Grand Total						1.387	0.282	0.419

[a] Based on average number of occupants per shelter.

the NSS shelter requirements, producing a total of 3.4 million dosimeters, 1.3 million chargers, and 1.4 million survey meters at a total cost of $75 million dollars, as summarized in Table 4.3.

Table 4.3. Minimum Instrument Requirements for Shelters, without Supplementary Instrumentation (Allocation B)

Instruments	Estimated Requirement (million $)	Estimated Cost per Instrument ($)	Total Estimated Cost (million $)
Survey meters	1.2	20	24
Dosimeters	2.4	10	24
Chargers[a]	1.2	10	12

[a]Fiber-optics dosimeters would not require chargers.

Although this apportionment may provide adequate instrumentation to guarantee equal radiation exposure, there will be insufficient instrumentation to provide a record of dose for more than a small percentage of the sheltered population.

4.4 Instruments Required for Maintaining Dose Records (Allocation C)

In this final case, dosimeters will be allocated according to the scheme in Table 3.7, based on the organization of shelter occupants into units. In order to provide a fairly accurate estimation of dose for all shelter occupants, the number of people per unit should be specified by shelter management to be from 7 to 12 members, depending on shelter configuration and variability of PF and in accordance with the Shelter Management Textbook (Department of Defense, 1967). An approximate average of ten people per unit was used in the preparation of Table 4.4. In shelters with large rooms and uniform PF, the number per unit could

Table 4.4. Instrumentation Allocation for Monitoring Dose of Shelter Occupants

Number of Shelters Occupied[a]	Average Number of Occupants per Shelter[a]	Average Number of Shelter Units per Shelter (~10 per unit)	Allocated per Shelter			Total Allocated (millions)		
			Dosimeters[b]	Chargers	Survey Meters	Dosimeters	Chargers	Survey Meters
Risk Areas								
25,263	14	2	4	1	1	0.101	0.025	0.025
28,816	33	3	6	1	1	0.173	0.029	0.029
21,659	72	7	9	1	1	0.195	0.022	0.022
18,294	145	15	17	2	1	0.311	0.037	0.018
18,438	320	32	36	5	2	0.664	0.092	0.037
8,131	696	70	74	9	3	0.602	0.073	0.024
5,381	2336	234	250	31	12	1.345	0.167	0.65
Total						3.391	0.445	0.220
Nonrisk Areas								
9,492	14	2	4	1	1	0.038	0.009	0.009
14,774	36	4	8	1	1	0.118	0.015	0.015
14,798	74	7	9	1	1	0.133	0.015	0.015
14,588	147	15	17	2	1	0.248	0.029	0.015
16,962	322	32	36	5	2	0.611	0.085	0.034

Table 4.4. (continued)

Number of Shelters Occupied[a]	Average Number of Occupants per Shelter[a]	Average Number of Shelter Units per Shelter (~10 per unit)	Allocated per Shelter			Total Allocated (millions)		
			Dosimeters[b]	Chargers	Survey Meters	Dosimeters	Chargers	Survey Meters
8,348	706	71	75	9	4	0.626	0.075	0.033
7,832	2297	230	246	31	11	1.927	0.243	0.086
Total						3.701	0.471	0.207
Grand Total						7.092	0.916	0.427

[a] Per Table 3.6.
[b] Per Table 3.7.

possibly be doubled. The number of chargers, if required, was allocated on the basis of approximately one charger per eight dosimeters. Survey meters were estimated at one per approximately 200 occupants as in allocation B.

These allocations resulted in requirements of 7.1 million dosimeters, 0.9 million chargers, and 0.4 million survey meters for the occupants of NSS shelters.

It will be assumed that shared home basement shelters will be organized into an average of five shelter units. According to Table 3.6, 11 dosimeters would be allocated to each shared home basement shelter. With one charger and one survey meter per shared home basement shelter, the total requirements for approximately one million shelters are 11 million dosimeters, 1 million chargers, and 1 million survey meters.

The total number of shelter instruments required is shown in Table 4.5. The necessary instruments include 1.4 million survey meters, 18.1 million dosimeters, and 1.9 million chargers, if the dosimeters are all of the fiber-electroscope type. The total cost for these instruments would be about $228 million.

Table 4.5. Instrument Requirements for Monitoring Dose of Shelter Occupants (Allocation C)

Instruments	Estimated Requirement (million $)	Estimated Cost per Instrument ($)	Total Estimated Cost (million $)
Survey meters	1.4	20	28
Dosimeters	18.1	10	181
Chargers[a]	1.9	10	19

[a]Fiber-optics dosimeters would not require chargers.

4.5 Conclusion

Three bases for allocating radiological instruments to shelter occupants have been presented. The number of dosimeters required were 2.4, 3.4, and 18.1 million; survey meters, 1.2, 1.4, and 1.4 million; and the costs, \$60, \$75, and \$228 million. The lowest cost basis of allocation was not recommended, because it resulted in inadequate instrumentation for many shelters. The costs per instrument may become reduced in mass production; therefore, the largest allocation of instruments with its potential for exposure control will become increasingly attractive.

Appendix A

REPORT OF WORKING GROUP ON CITIZENS' INSTRUMENTS

ADVISORY COMMITTEE ON CIVIL DEFENSE
NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
JANUARY 1960

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington 25, D.C.

Advisory Committee on Civil Defense

REPORT OF WORKING GROUP ON CITIZENS' INSTRUMENTS

At the request of the OCDM, the Advisory Committee on Civil Defense formed a working group to consider and advise on "the problems involved in providing radiological instruments for individual citizens." On January 22, 1960, the Group met at the National Bureau of Standards.

Members Present:

Chairman, Lauriston S. Taylor, National Bureau of Standards
Richard W. Johnston, Atomic Energy Commission
Harry J. Watters, White House Staff
John K. Hemphill, Educational Testing Service
A. P. Hammel, New York State Interdepartmental Committee on Fallout Protection
Richard B. Roberts, Carnegie Institution of Washington
Victor P. Bond, Brookhaven National Laboratory
C. J. Borkowski, Oak Ridge National Laboratory
John T. Lanzetta, University of Delaware
Secretary, Richard Park, National Academy of Sciences

Others Present:

George W. Baker, National Academy of Sciences
James O. Buchanan, Office of Civil and Defense Mobilization
Jack C. Greene, Office of Civil and Defense Mobilization
Robert B. Martin, Office of Civil and Defense Mobilization
George D. Rich, Office of Civil and Defense Mobilization
Edward R. Saunders, Office of Civil and Defense Mobilization

The discussion centered about the following statement which is contained in the June 1953 report of the NAS Advisory Committee on Civil Defense entitled "The Adequacy of Government Research Programs in Non-Governmental Defense".

"The final effectiveness of shelter depends upon the occupants of any shelter having simple, rugged, and reliable dose-rate meters to measure the fallout dose rate outside the shelter".

After briefings by OCDM on fall-out patterns and forecasts, on the national radiological monitoring system, and on the citizen's instrument research and development program, the Working Group on Citizens' Instrument concentrated its attention primarily on three aspects of the citizen's instrument problem. (It was implicit throughout the discussion that the likely "user" of the citizen's instrument would be an average, middle class high school graduate, with little technical training, but relatively sound faculties and reasonably high intelligence.)

Aspect 1. What kind of decisions would need to be made by a shelter occupant or by an individual who might have to seek shelter?

What type of information would be needed in order to implement these decisions?

Aspect 2. By what means would the required information be obtained?

Since the information could undoubtedly be obtained by some means of instrumentation, what would be the desirable techniques of the instrument?

Aspect 3. Having obtained information from suitable instruments, how would this information be used?

What are the problems involved in the proper interpretation of instrument readings?

How will individuals be trained to use this information?

Information Needed

The Group considered the several possible actions that people might take in a fall-out attack situation. These included the determination of when and where to seek shelter, judging the adequacy of shelter, estimating how long to stay, determining the hazard of making short excursions, etc. The Group agreed that, since all such decisions and actions depended on quantitative information on dose rate and/or accumulated dose, instruments should measure, and be readable in, some unit from which an estimate of the degree of hazard could be derived, such as roentgen/hr.

After some discussion, it was recognized that a proper civil defense system should include a nationwide means for warning the population of an impending attack and a system for informing people following attack, particularly concerning fall-out danger. Because it was felt that a nationwide, official, monitoring system could not readily provide information on fall-out to isolated rural regions, and could not adequately reflect the possible large local variations in fall-out intensity, the Group agreed that it would be very important for shelter occupants to have first-hand information as to their immediate local conditions.

Finally, the Group, in considering the type of information required, concluded that an instrument that provided only an alarm or "go/no go" type of information was not adequate.

Desirable Characteristics of a Citizens' Instrument

On the basis of the type of information needed, as discussed above, it was agreed that a citizen's instrument should have the following general characteristics:

1. The instrument should give quantitative information. One that gives only an alarm is not needed.

2. Its dependability would be of the utmost importance.

3. There should be an instrument that reads either dose or dose rate, provided there are simple instructions or procedures for getting one from the other.

4. The instrument should be capable of measuring both inside and outside shelter.

5. The instrument should be available in every shelter.

6. The instrument should be usable by "average" people.

The Working Group examined these broad requirements and discussed them in terms of the specific characteristics desirable in a citizen's instrument. The Group listed the following idealized characteristics as those which should be sought, realizing that some are probably unattainable, and emphasizing that these are not put forth as fixed specifications. They include:

- No batteries (e.g. deriving energy from such sources as the piezoelectric phenomenon)
- Infinite shelf-life
- Rugged
- Easy calibration and maintenance
- Low cost
- Direct reading
- Simple scale
- Accuracy (to OCDM specifications of $\pm$ 35%)
- Energy independent
- No geotropic response dependence
- Simple
- Positive operation test
- Range 1-100 r/hr, (useful readings in the 100 to 1000 r/hr range would be an asset)
- Fail safe

Considerable attention on the part of the Working Group was given to the development of an instrument scale having simple characteristics, since, in the last analysis, there will be a limited number of decisions that can be made by the relatively untrained individual. For example, there might be ten ranges of conditions involving varying decisions. Therefore, the scale might be divided into ten parts, (using r/hr as basic unit) with each part carrying a certain range of decisions. At the same time, because of the inherent inaccuracy of the decision, there is little point in having high accuracy in the instrument readings.

No particular kind of instrument was recommended for meeting these requirements; other than that the instrument should be quantitative in its indications.

Further, there was general agreement that serious consideration be given to studying piezoelectric, electrostatic, or allied phenomena which would replace batteries as the energy source for citizen's instrument.

Use of the Instrument

The problems entailed in the effective use of a citizen's instrument are, in the opinion of the Working Group, very serious, perhaps more so than the problem of developing an instrument. These problems include that of persuading people in significant numbers to buy the instrument, and the even more difficult one of how readings should be interpreted so that they result in the proper decisions for action.

The Working Group concluded that if people, through education, are persuaded to build shelters for themselves, they would be apt to buy the instrument, provided the cost was reasonably low. The possibility of making a public survey of why people do not take such independent action was discussed and further consideration was urged.

With regard to the second problem, i.e., proper interpretation of readings, the need for a simple scale on the instrument and for a good manual was re-emphasized. The Working Group unanimously endorsed the suggestion regarding format and context of the manual, i.e., for each of the limited number of readings on the scale of the instrument and for a limited number of time intervals (after explosion) there should be a brief paragraph of instructions on recommended courses of action with regard to making excursions from shelter, seeking a safer place, etc.

The Group felt that such a procedure offered the best chance of reflecting such facts as acceptable dose levels, and dose already received. The Group also agreed that such a manual, to be effective, must be prepared with extreme care and preferably reflect human engineering and data presentation principles as well as knowledge of radiation and its effects.

Major Conclusions

1. As a supplement to the official radiation monitoring system, each shelter group should have a radiation detection instrument capable of giving quantitative readings in some unit of the hazard, such as roentgen per hour. A simple alarm or "go/no go" instrument is not at all adequate.

2. Several of the desirable characteristics of such an instrument are extremely difficult to provide (no batteries, infinite shelf-life, positive operation test, etc.). There is little doubt, however, that an

instrument can be provided that will be satisfactory, even though it does not meet all such criteria.

3. Perhaps the most difficult aspect of the problem is that of ensuring the effective use of a citizen's instrument, specifically, the proper interpretation of instrument readings, including application of available knowledge of acceptable dose levels, and the translation of such information into effective protective action for people to take when under fall-out attack.

4. The most promising procedure for solving this problem of the proper use of a citizen's instrument is believed to be the preparation of a manual of instructions (to accompany each instrument) that, for each of a limited number of instrument readings and a limited number of elapsed time intervals after explosion, contains a brief paragraph clearly stating the recommended courses of action with regard to excursions from shelter, etc. Such a manual should be prepared through the joint efforts of people knowledgeable concerning radiation levels and effects, decay rates, shielding, etc., and those versed in human engineering and data presentation.

Appendix B

THE CITIZENS' INSTRUMENT

ADVISORY COMMITTEE ON CIVIL DEFENSE
SUBCOMMITTEE ON CITIZEN'S INSTRUMENTS
NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
DECEMBER 1962

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue, Washington 25, D.C.

Advisory Committee on Civil Defense
Subcommittee on Citizens' Instruments

THE CITIZENS' INSTRUMENT

In January, 1960, the Working Group on Citizens' Instruments met and prepared a report summarizing its views on the problem of providing the individual citizen with an instrument for detecting radiation.

The Working Group, which was reconstituted as a Subcommittee in April 1962, decided at its third meeting in December 1962 to revise and reissue its 1960 report, emphasizing the three phases of the Citizen's Instrument problem considered most important:

1. What type of instrument should be made available;
2. how can such an instrument be developed; and
3. what guidance to users of the instrument should go with it.

<u>Members</u>

Dr. Robert D. Huntoon, Chairman - National Bureau of Standards
Dr. Victor P. Bond - Brookhaven National Laboratory
Dr. C. J. Borkowski - Oak Ridge National Laboratory
Mr. Jack C. Greene - Office of Civil Defense
Mr. Alvin P. Hammel - New York Telephone Company
Dr. John K. Hemphill - Educational Testing Service
Dr. John Lanzetta - Fels Research Institute
Mr. Robert Martin - Office of Civil Defense
Mr. Richard Roberts - Carnegie Institution of Washington
Dr. F. R. Shonka - St. Procopius College
Dr. Lauriston S. Taylor - National Bureau of Standards
Dr. Harry J. Watters - Radio Corporation of America
Mr. Richard Park, Secretary - National Academy of Sciences

Desirable Characteristics of the Citizens' Instrument

It was agreed that a citizen's instrument should have the following general characteristics:

1. The instrument should give quantitative information on gamma radiation only. One that gives only an alarm is not adequate.
2. It should be at least as reliable as a good watch.
3. It should be an instrument, or pair of instruments, that reads both dose and dose rate and indicates those readings separately.
4. The instrument should be capable of taking a wide range of readings and thus give meaningful measurements both inside and outside shelter, e.g., from mr or mr/hr to hundreds of r or of r/hr.
5. Its shelf-life should be extremely long (10's of years), and its cost, size, weight, and portability should be such as to make it easy for every shelter to have one.
6. The instrument should be usable by "average" people, without undue amounts of training, practice, etc.

The Subcommittee examined these characteristics and discussed them in terms of how to provide them in a citizen's instrument. It was fully realized that some of the requirements are difficult to achieve today.

Idealized Specifications of Citizens' Instrument

The Subcommittee agreed on the following as a list of idealized, rather than fixed, specifications:

1. No batteries (e.g., deriving energy from such sources as the piezoelectric phenomenon)
2. Infinite shelf-life
3. Rugged, light weight, and portable
4. Easy calibration and maintenance
5. Low cost
6. Direct reading
7. Simple scale
8. Accuracy (to OCD specifications of $\pm$ 35%)

9. Energy independent (responding between 80 KEV and 1.2 MEV to an accuracy of $\pm$ 35%, and only to gamma radiation)
10. No geotropic response dependence
11. Simple
12. Positive operation test
13. Range 100 mr per hr to 1000 r per hr (in view of the state of the art instruments reading between 1 and 100 r per hr should be considered acceptable today)
14. Fail safe

In discussing range, it was recognized that range-changing might, for the present, be by far the most feasible method for achieving the range given above. Because of the gross errors that range changing might introduce, it was agreed that it is undesirable, but might have to be accepted for the time being.

Use of the Citizens' Instrument

The providing of guidance or instructions on the use of the instrument remains a most difficult problem, in the opinion of the Subcommittee. There are many variables that must be known in order to make good decisions on such matters as duration of shelter occupancy, the need to seek better shelter, and the making of brief excursions outside. The Subcommittee agreed that it was inconceivable that a citizens' instrument could provide readings on such vitally important variables as time since burst, or could distinguish among multiple bursts and overlapping fallout patterns.

There was general agreement that any guide or instructions on the use of citizens' instrument should be strictly limited to actions based on the information that can reasonably be expected to be available to shelterees. Thus, with instruments only capable of giving accumulated dose and current dose rates inside and outside the shelter, guides should be confined to indicating courses of action that depend only on these variables. For example, it might be useful to use a bank account analogy in giving instructions: Thus a shelteree who is considering whether and for how long to leave shelter to accomplish some task, can read how much radiation he has accumulated since entering shelter, and what the r/hr is outside shelter at that moment; then, he could see how much additional radiation he could accept before he used up his "bank balance" by reaching a total dose of - say - 200 r. There is a philosophy behind this approach that recognizes that it is impossible to foresee what factors might affect such a decision; therefore the decision can only be made on the spot when the factors are known.

The Subcommittee urges that the OCD continue efforts to arrive at a satisfactory guide for use with citizens' instruments that recognizes this philosophy and that is limited to advice on actions that can be based on data that would be available.

Appendix C

NUMBER OF SHARED HOME BASEMENT SHELTERS

APPENDIX C: NUMBER OF SHARED HOME BASEMENT SHELTERS

Home basements which are shared with nonoccupants as fallout shelters have been included for allocation of federal radiological defense instruments in Sect. 4. The number of home basements which are shared as shelters can be estimated from data accumulated in the investigations in Appendices D and E, by a method which will be described here.

When limits on home basement occupancy were increased from 5 to 50, by a factor of 10 as described in Appendix D, the number of available basement spaces increased to 1.83 billion, or about nine times the 1970 population of the United States. Yet the increase in basement occupancy in the Community Shelter Plan (CSP) model was only about 44 million when the basement preference (BP) over NSS shelters was 100%, as shown in Table C.1, regardless of the NSS shelter posture. Furthermore, when the travel distance was increased from 1 to 5 miles, the increase in basement occupancy was increased only from 131 to 133 million (BP = 100%), less than 2%.

One conclusion which may be drawn from these observations is that a large fraction of the number of home basements are located where they are too far away from populations which need shelter under CSP, and the shelter space which they afford is not needed for sharing by the population within range. This conclusion may be used to estimate the number of basements in which owners share their shelters. Radiological instruments would presumably be supplied by the federal government to the owners of these homes.

In the case where the limits on basement occupancy were changed from 5 to 50, the additional (174.8 - 130.6) 44.2 million people sheltered (BP = 100%, Table C.1) could be accommodated in 44.2/(50 - 5) = 0.98 million basements, if each were filled to their specified capacity of 50 people. But they will not all be filled to capacity because in some localities there will not be enough people within the travel radius. Hence a larger number than 0.98 million home basements would be shared in actuality.

In the case where the limits were changed from 5 to 10, the additional (147.1 - 130.6) 16.5 million people sheltered (BP = 100%, Table C.1)

Table C.1. National Home Basement Occupancy

Limit per Basement	Travel Distance (Miles)	Number in Basements (millions) for Stated Posture					
		BG NSS[a]		R/NR[b]		All NSS[c]	
		BP = 0%	BP = 100%	BP = 0%	BP = 100%	BP = 0%	BP = 100%
5	1	95.33	130.61	88.55	130.62	68.73	130.48
10	1	107.40	147.14	99.08	147.16	77.45	146.97
20	1	117.40	159.42	106.69	159.42	84.61	159.14
50	1	130.58	174.83	119.21	174.82	94.19	174.47
5	5	98.87	132.62	91.94	132.61	71.15	131.67

[a] Only belowground NSS spaces and home basements available.

[b] All NSS spaces and home basements available, except in risk areas, where number of NSS spaces is reduced.

[c] All NSS spaces and home basements available.

could be accommodated in 16.5/(10 - 5) = 3.3 million basements, if each were filled to their capacity of 10 people. Again, these basements would not all be filled to the limit of 10 because of insufficient people in some areas; and, again, a larger number than 3.3 million shared home basements must be used, if the limit of 10 per basement is imposed.

However, the average number of people which can be sheltered in a home basement under emergency conditions will exceed 10 (see Subsect. E.2.3, Appendix E). When the occupancy limit is raised well above 10, say to 20 or more, the number of basements required for shared sheltering may drop to less than the 3.3 million estimated above, but would be greater than 0.98 million. A detailed investigation of shelter postures with the data bases and algorithms described in Appendices D and E would be necessary to obtain this number more accurately, and could also specify the areas in which on-site surveys should be made. For this study, an average number for shared basements will be developed as described below, following the heuristic argument given above and using the available data in Table C.1.

We assume that a certain number, B_r, of home basements are in areas, presumably rural, where they are not accessible or needed for sharing in the CSP. Let K represent the total number of home basements in the United States. Then $K - B_r$ represents the number of basements in which sharing may occur.

Let N_j represent the total number of people (in millions) in basements where the limited occupancy is j people per basement. The values of j can then be 5, 10, 20, and 50, according to the data available in Table C.1.

If B_i represents the number of home basements with i people actually occupying each of the B_i basements, then the following set of equations describes all home basement occupancy postures:

$$\sum_{i=1}^{i=j} B_i i = N_j \quad , \qquad (1)$$

$$\sum_{i=1}^{i=j} B_i = K \quad . \qquad (2)$$

The numbers B_i are indeterminable with the available data in Table C.1. The number of rural basements, B_r, may be assumed to remain unchanged for all j. The average number of occupants per rural basement will be designated by r, which will also remain fixed for all j. The four basement postures in Table C.1, corresponding to a travel distance of 1 mile, can then be represented by the equations

$$B_r r + B_j j = N_j \quad , \tag{3}$$

$$B_r + B_j = K \quad . \tag{4}$$

Substitution of B_j from (4) into (3) results in

$$B_r r + (K - B_r) j = N_j \quad , \tag{5}$$

from which

$$r = \left[N_j - (K - B_r) j\right] / B_r \quad . \tag{6}$$

Four solutions for r in Eq. (6) result, corresponding to the four available values of j. Elimination of r can be obtained in six possible combinations, resulting in six values of B_r which are then averaged. The results are shown in Table C.2. For the estimation of the number of instruments required, as discussed in Sect. 4, the number of shared home basement shelters was assumed to be one million. The total number of home basements in the U.S., 36.65 million, the value for K, includes 0.5 million vacation homes which are not normally occupied. The average value for r, the average number of occupants in homes which do not share basements, was about three persons.

Table C.2. Estimated Number of Shared Home Basement Shelters (in Millions)

	BP = 100%	BP = 0.0%		
		BG NSS[a]	R/NR[b]	All NSS[c]
Rural Basements (Not Shared)	35.21	35.54	35.70	35.85
Shared Basements	1.44	1.11	0.95	0.80

[a]Only belowground NSS spaces and home basements available.

[b]All NSS spaces and home basements available, except in risk areas, where number of NSS spaces is reduced.

[c]All NSS spaces and home basements available.

Appendix D

ORNL SHELTER AVAILABILITY DATA BASE

APPENDIX D: ORNL SHELTER AVAILABILITY DATA BASE

D.1 Introduction

The number of radiological instruments required to protect people in shelters depends on a number of parameters as described in Sect. 3. To make first-order estimates of this number it was necessary to determine how people might be distributed within community shelters after a nuclear attack. This determination required information on the type and location of shelter available. Two classes of shelter were considered; public shelters were augmented by home basements to provide a more realistic appraisal of potential shelter. Designated public fallout shelters were listed in the National Shelter Survey (NSS), while a count of home basements was obtained from the 1970 United States census.

Figure D.1 illustrates schematically the steps in the creation of the ORNL shelter availability data base. Each step will be identified and discussed in more detail in this appendix.

Combining the NSS facilities and home basements was not a straightforward procedure, since each data set had a different areal basis. The public shelters were identified with one of the 43,000 1960 Standard Location Areas (SLAs), each about the size of a census tract. All 1970 census data were given for Enumeration Districts (EDs) or block groups. These 256,000 census units will be referred to as EDs.

D.2 Public Shelter Facilities

D.2.1 National Shelter Survey.

In 1961 the National Shelter Survey Program was initiated to identify usable shelter space in existing structures to protect the United States population from the hazards of a nuclear attack. In the early years, structures were evaluated only on their potential for fallout shielding. Facilities in areas with risk of blast (those with a 50% or better probability of 2 psi or greater blast overpressure) have now been partially resurveyed to determine their vulnerability to blast and fire. Space is restricted to 10 ft^2 (0.93 m^2) per person. This area is also considered the minimum space per occupant for fallout protection. The

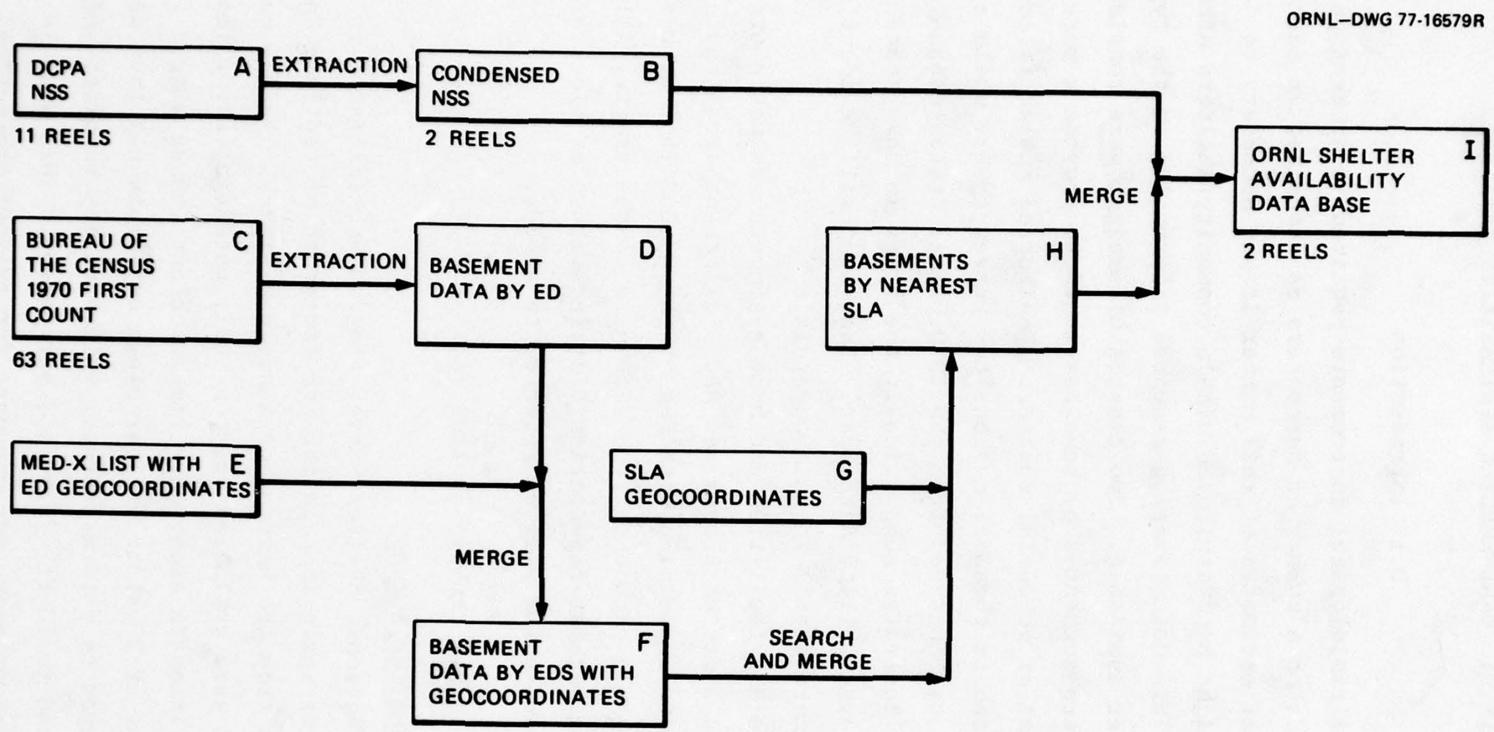

Fig. D.1. Creation of the ORNL shelter availability data base.

number of designated underground spaces has also been further limited where there is inadequate ventilation (Department of Defense, 1975c).

Because of the large size of the NSS data base, other approximations or substitutions for the NSS data were considered. The data for areas which had completed the more detailed "all-effects" surveys were examined. The number of these areas was small, and they were almost exclusively urban communities. It seemed unreasonable to consider these data to be typical of the entire nation. Without a valid representation of the public shelters, the only approach was to use the actual NSS data file.

Eleven reels of computer tapes comprising the NSS file as of December 1976 were obtained from the Defense Civil Preparedness Agency (DCPA) computer center (see block A in Fig. D.1). The seven-track DCPA tapes, prepared for a CDC 3600 computer, were copied onto nine-track tapes for use on ORNL's IBM 360 machines. The NSS summary file (record type 8) was then addressed to obtain the desired shelter information.

For the benefit of others who may be transferring data from one type of computer to another, it may be worthwhile to relate the problems which occurred when we attempted to read binary data from the NSS summary file; DCPA had compressed some of the numerical data into binary form to reduce the amount of tape required to store the file. The CDC 3600 stored the data in six-bit bytes. The IBM 360 read the data byte by byte, adding two zeros to the left of each six binary digits to fill out its eight-bit byte. This produced an incorrect number in most cases, averaging about four times too large. Once this problem was recognized, the computer program was modified to read the binary data correctly.

The standard location, special facility, relative blast protection (PV), and use and owner codes were utilized, along with the number of belowground fallout spaces and the protection factor (PF) breakdown of all the shelter spaces.

D.2.2 Interpretation and reduction of file.

Three sample records from the NSS summary file are shown in Fig. D.2. These three listings are from one SLA in Auburn, Maine. Records like these on the 11 reels of NSS data were extracted and condensed to

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STANDARD LOCATION  FACILITY  SPEC.            CODES                RADEF B  BLST   BELOW                               SPACES
RSAC  9DIG  TRACT   NUMBER    FAC.  LIC. POST UPDT HEW PV USE OWNER  KITS  P  BSMT  GROUND    PF28    PF1    PF0    PF48    PF2
1211   0    0001    01032     6     1    1     2    0  71  44   3     01        0     194      194     0      0      92     102

   SPACES                                   COORDINATES
   PF3   PF4   PF5   PF6   PF7   PF8        LONG.   LAT.                 NAME AND ADDRESS OF FACILITY
   0     0     0     0     92    0                              UNDERGROUND CONTROL CENTER AUBURN AIRPT


STANDARD LOCATION  FACILITY  SPEC.            CODES                RADEF B  BLST   BELOW                               SPACES
RSAC  9DIG  TRACT   NUMBER    FAC.  LIC. POST UPDT HEW PV USE OWNER  KITS  P  BSMT  GROUND    PF28    PF1    PF0    PF48    PF2
1211   0    0001    01038     -     1    1     2    0  32  43   1     01        0     74       74      0      0      74      0

   SPACES                                   COORDINATES
   PF3   PF4   PF5   PF6   PF7   PF8        LONG.   LAT.                 NAME AND ADDRESS OF FACILITY
   0     0     74    0     0     0                              POST OFFICE TURNER STREET


STANDARD LOCATION  FACILITY  SPEC.            CODES                RADEF B  BLST   BELOW                               SPACES
RSAC  9DIG  TRACT   NUMBER    FAC.  LIC. POST UPDT HEW PV USE OWNER  KITS  P  BSMT  GROUND    PF28    PF1    PF0    PF48    PF2
1211   0    0001    01040     -     1    1     6    0  36  61   4     01        0     808      1164    837    0      294     870

   SPACES                                   COORDINATES
   PF3   PF4   PF5   PF6   PF7   PF8        LONG.   LAT.                 NAME AND ADDRESS OF FACILITY
   0     172   61    61    0     0                              CUSHMAN HOLLIS CO 209 COURT ST
```

Fig. D.2. Sample of NSS shelter listing.

fit two reels of tape. It was necessary to reduce this data base in order to reduce the time and costs of subsequent computer operations.

Several changes were made in the condensation process. The facility number was examined to identify sensitive facilities (those requiring security clearance for entry). If this number began with 2, 4, 6, 8, or 9, the listing was dropped, since these spaces would usually not be available to the general public. DCPA's protection categories 2 and 3 were combined and given a nominal PF of 70 to correspond with previous DCPA in-house studies (Bensen, 1977). Other protection factors were assigned in accordance with Table D.1.

Table D.1. Assignment of Protection Factor

DCPA Protection Category	Range of Protection Factors		Protection Factor Used
0	10-19		15
1	20-39		30
2	40-69	combined	70
3	70-99		
4	100-149		125
5	150-249		200
6	250-499		375
7	500-1000		750
8	Over 1000		2000

The three listings in Fig. D.2 now appear as in Table D.2 (block B in Fig. D.1). Headings have been added to identify the information. The detailed description of each facility has been omitted. For example, the first entry in Table D.2 indicates the general descriptive characteristics of the building, but does not show that it is the underground

Table D.2. Sample of Condensed NSS Listing

Standard Location Area	Special Facility	PV	Use	Owner	Spaces Below-Ground	PF Values							
						15	30	70	125	200	375	750	2000
1211 0001	6	71	44	3	194	0	0	102	0	0	0	92	0
1211 0001	-	32	43	1	74	0	0	0	0	74	0	0	0
1211 0001	-	36	61	4	808	0	837	870	172	61	61	0	0

control center at the Auburn, Maine, airport. The coding reveals it is an earth-covered, storage-type special facility used as a communication facility and owned by the local government. The second entry, which the detailed description identifies as a post office, is described in the condensed version as a single-story industrial or commercial wall-bearing structure, federally owned, and used as a utility. The Cushman Hollis Company (third entry) is described as a 3-5 story, wall-bearing building, privately owned, and used as a factory, plant, or manufacturing facility.

The location code places all three shelters in the same SLA. The first four characters of the location are the region, state, and area code (RSAC) for the area. An RSAC, with the exception of some parts of New England, corresponds to a county-type unit. The code "1211" identifies the RSAC as the Lewiston-Auburn SMSA part of Androscoggin County, Maine. A new condensed file of the nonsensitive NSS shelters, containing characteristics and locations, was created in this way.

D.2.3 Belowground NSS shelters.

A second NSS file was prepared to include possible changes in the use of shelters due to the blast threat from nuclear explosions. This data base further reduced the original listing to one reel of tape by removing all spaces not designated as belowground. When the total number of spaces exceeded the belowground sum, the excess spaces were deleted, and the remaining basement spaces were assumed to have the highest PF values. The third listing in Table D.2 would be modified to read as follows:

1211 0001 - 36 61 4 808 0 0 514 172 61 61 0 0 .

If the total in the PF categories were less than the belowground number, the PF value was considered correct, and all spaces were assumed to be below ground level. This procedure, as we later discovered, omitted listing some caves and tunnels. These facilities would provide excellent blast protection, but their spaces had not always been characterized as belowground in the NSS summary file.

D.2.4 Risk-modified NSS File.

The risk-modified list of NSS shelters was created in an attempt to encompass blast protection for the threatened population, while making as much NSS space as possible available in nonrisk areas. All SLAs with geographical centroids within an area subject to 2 psi (13.79 kPa) or greater overpressure from a detonation in the hypothetical CRP-2B attack (Department of Defense, 1975a) were considered risk areas. The location of these blast zones is shown in Fig. D.3. All nonsensitive NSS shelter spaces were included in the nonrisk area and divided into the same PF categories as before.

Within the risk SLAs, the number of available NSS shelter spaces was reduced. Spaces in sensitive facilities and those designated in the file as aboveground, except for special facilities (caves, tunnels, etc.), were again deleted. Any remaining spaces in DCPA protection categories 0 and 1 were also removed. Permissible shelter in the risk areas consisted of special facilities and shelter spaces identified as underground with an average protection factor of 40 or greater.

D.3 United States Census Data

D.3.1 Summary tapes.

Housing units with basements were enumerated April 1, 1970. Structures were considered to have basements if they had accessible enclosed space below all or part of the structure, deep enough for an adult to walk upright, and belowground on at least part of its perimeter. The United States Bureau of the Census had created two files of summary tapes from the first count from the complete-count files used to prepare the tables for the Census of Population and Housing, vol. 1, Chap. A (block C in Fig. D.1). File A was used to obtain data for smaller areas such as enumeration districts and block groups not included in the printed reports. This file contained information on race, sex, age, household composition, marital status, and housing charcteristics, including value, rent, facilities, tenure, and race of household head (Bureau of the Census, 1970). Basement and population data were extracted from this file (block D in Fig. D.1).

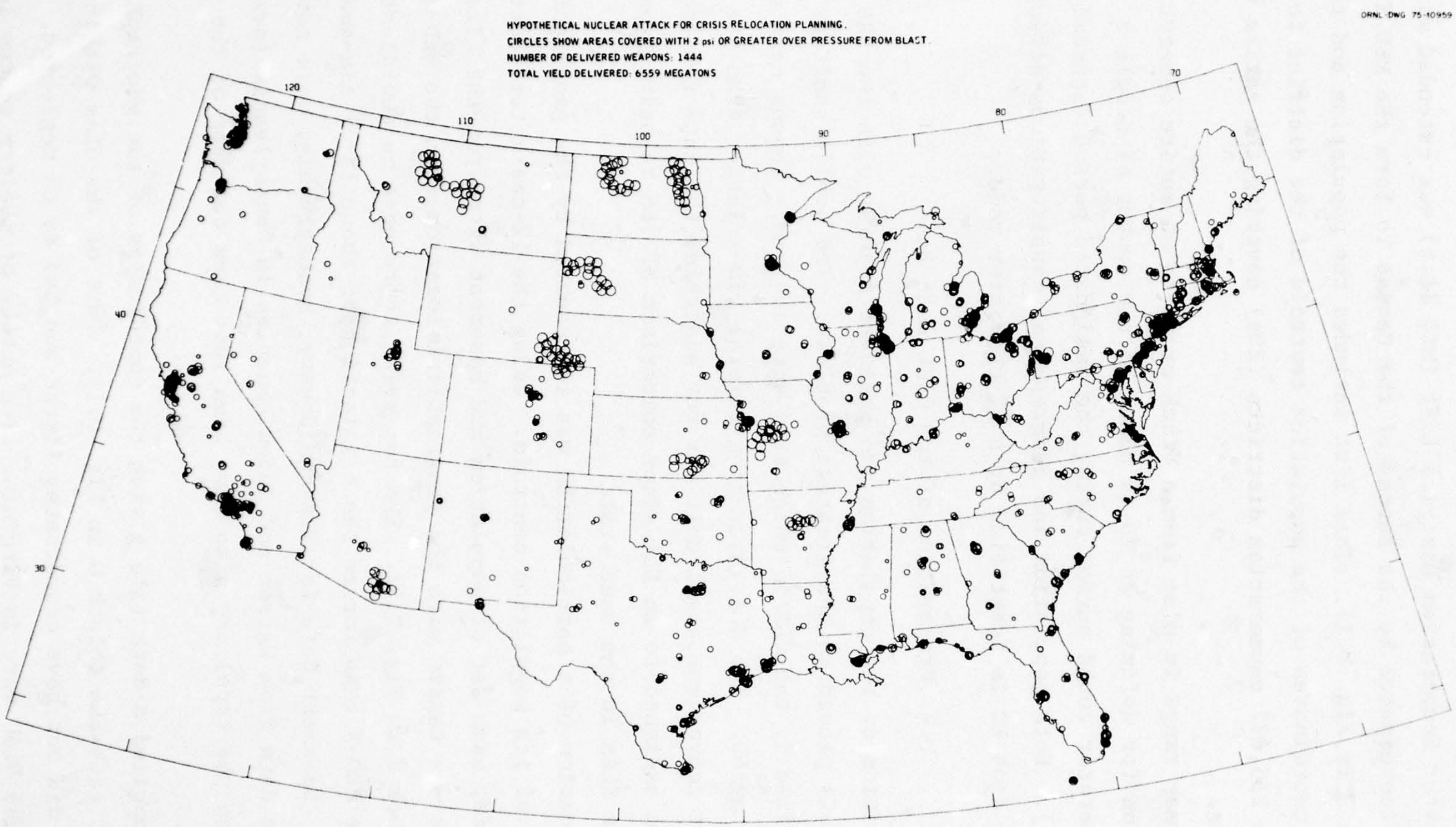

Fig. D.3. Areas subject to overpressures of 2 psi (13.79 kPa) or greater from hypothetical CRP-2B attack.

D.3.2 Master enumeration district list.

The Master Enumeration District List (MED list) was extended with geographic coordinates by the Bureau of the Census to form the MED-X list (block E in Fig. D.1). This list includes the population and the geographic coordinates of the population centroid of the district for each of the 255,627 enumeration districts (EDs) covering the entire area of 50 states.

An ED may range in size from a block group to an entire county. The criterion for defining an ED is based on the number of people a census enumerator could survey during the designated period (approximately 1000). Both population and geographical considerations affect this size. Each ED is identified by a 12-character code.

D.4 Preparation of the ORNL Data Base

Combination of the population and basement figures with the NSS shelter totals presented the greatest problems. The public shelters were identified by the SLA in which they were located. Census data were accumulated by ED. The SLA, averaging several times larger than the ED, was the most convenient areal unit for our analysis; the data for each ED were then assigned to an SLA after comparison of its relative proximity to all other SLAs in the same state.

The location of a particular ED was represented by the geographic coordinates of its population centroid. Using the 12-character identification code, each set of population and basement data from the first count census was tagged with the geographical location from the MED-X listing (block F in Fig. D.1). EDs for which there were no coordinates given on the MED-X tape forced the elimination of about 1% of Alabama's population. Basement data for Venango County, Pennsylvania, were never found. Some data from Warren and Union counties in Pennsylvania (next to Venango on the tape) may also have been lost from our copy of the census file.

DCPA supplied a data file giving the coordinates of the geographical centroids of each SLA (block G in Fig. D.1). Part of the SLAs within seven RSACs did not have coordinates listed and had to be neglected. Seven of these SLAs were in Virginia. The number of shelter spaces lost

AD-A058 806 OAK RIDGE NATIONAL LAB TENN F/G 13/13
INSTRUMENTATION REQUIREMENTS FOR RADIOLOGICAL DEFENSE OF THE U.--ETC(U)
AUG 78 C M HAALAND, K S GANT W-7405-ENG-26
UNCLASSIFIED ORNL-5371 NL

2 OF 3
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CONT

was not considerable except in Virginia Beach and Salem (20,893 and 25,832 respectively).

The distances between the centroids of each SLA and each ED within a state were calculated. The population and basements associated with each ED were assigned to the nearest SLA (block H in Fig. D.1). Several EDs could be assigned to one SLA if it were closer than any other.

As a validity check, an ED was eliminated if its centroid were 100 miles (161 km) or more from the nearest SLA within the state. Although this process may have unwittingly eliminated one or two EDs in the Aleutian Islands, map verification showed almost all the EDs eliminated had incorrect coordinates. Only Minnesota, New York, and Virginia (Table D.3) lost more than 0.1% of the total basements in the state, and their losses were still small. Population lost through this process is assumed to be equally negligible.

The difficulties encountered in merging the NSS and census data may affect the total shelter available for certain individual counties, but would not be expected to have a noticeable effect on the state or national totals. Some of the difficulties in Virginia were undoubtedly due to the increasing number of county-type units resulting from the creation of independent cities. When possible and within the limits of our data, some of these changes were incorporated.

D.5 Shelter Availability

Shelter availability files were prepared using the home basement counts and the entire NSS file (block I in Fig. D.1), the belowground NSS file, and the risk-modified NSS file. For each of these assumptions on the suitability of NSS facilities, the number of public shelter spaces in each PF category and the number of home basements could be found for each SLA. In this study, all home basements were considered to provide possible shelter.

A state-by-state sum of all public shelters and spaces, home basements, and population, as well as national totals, appears in Table D.4. The national total of spaces rated with a PF of 40 or greater exceeds the population. A closer look at the state summaries demonstrates the uneven distribution of these spaces; some states have excess spaces with

Table D.3. Basements Lost by Eliminatig EDs More Than 100 Miles from the Nearest SLA

State	Basements Lost	Percent of Remaining Basements
AK	63	<0.1
CO	45	<0.1
FL	16	<0.1
GA	47	<0.1
IL	244	<0.1
KS	3	<0.1
MA	25	<0.1
MN	16,189	<1.5
NJ	13	<0.1
NY	8,090	<0.2
PA	94	<0.1
TN	5	<0.1
TX	90	<0.1
VA	4,506	<0.7
WI	185	<0.1

Table D.4. Available Shelter by States

State	Number of Facilities, PF < 40	Number of Spaces, PF < 40	Number of Facilities, PF ≥ 40	Number of Spaces, PF ≥ 40	Number of Houses with Basements	Population
AL	2,259	2,807,978	3,222	1,970,432	175,953	3,404,533
AK	64	160,893	547	252,321	86,948	296,970
AZ	2,109	1,335,605	2,619	1,170,982	71,505	1,760,623
AR	626	1,296,829	2,081	1,173,471	81,447	1,922,223
CA	4,756	13,241,484	14,874	20,279,915	1,157,223	19,690,510
CO	757	751,819	3,623	2,608,756	467,318	2,192,489
CT	1,037	2,446,617	5,300	4,026,048	869,174	3,005,669
DE	451	412,085	1,465	630,544	124,480	543,006
DC	527	216,828	8,976	7,162,303	241,665	750,693
FL	2,511	7,180,942	4,496	7,445,176	102,524	6,674,836
GA	2,894	6,115,901	5,471	5,421,672	318,288	4,549,991
HI	579	525,270	1,068	754,487	76,734	767,025
ID	129	213,211	1,002	449,682	176,071	712,567
IL	2,725	2,080,548	15,512	12,006,912	2,824,226	10,897,373
IN	3,113	4,176,245	6,096	3,940,135	995,454	5,090,223
IA	962	687,303	5,449	2,192,638	851,221	2,821,206
KS	1,590	1,648,145	5,515	2,518,835	475,064	2,215,856

Table D.4. (continued)

State	Number of Facilities, PF < 40	Number of Spaces, PF < 40	Number of Facilities, PF ≥ 40	Number of Spaces, PF ≥ 40	Number of Houses with Basements	Population
KY	1,546	1,758,593	3,343	2,954,512	449,874	3,171,724
LA	619	2,009,807	1,690	1,694,619	63,450	3,629,480
ME	635	709,243	1,586	789,676	276,282	992,048
MD	1,235	2,394,667	5,164	5,268,056	928,590	3,858,489
MA	3,062	3,951,788	11,351	8,023,594	1,689,219	5,629,160
MI	3,234	2,793,542	9,907	8,039,918	2,190,743	8,751,653
MN	1,146	1,909,492	8,224	6,608,754	1,062,263	3,692,410
MS	1,723	1,534,124	1,232	532,890	53,797	2,216,083
MO	1,321	2,087,593	7,050	6,206,223	1,112,334	4,649,669
MT	409	426,112	1,519	674,829	198,813	694,409
NE	539	359,507	3,288	1,537,417	425,138	1,437,718
NV	798	997,441	958	1,003,767	70,609	488,738
NH	261	735,167	1,075	588,968	216,393	737,681
NJ	2,471	2,661,163	17,542	8,811 245	1,898,328	7,115,600
NM	281	972,738	1,409	675,640	62,064	1,014,327
NY	3,340	4,349,298	82,614	41,454,129	5,343,758	17,893,370
NC	2,229	4,511,686	4,879	3,174,706	394,654	4,993,108

Table D.4. (continued)

State	Number of Facilities, PF < 40	Number of Spaces, PF < 40	Number of Facilities, PF ≥ 40	Number of Spaces, PF ≥ 40	Number of Houses with Basements	Population
ND	267	285,486	1,363	555,738	204,910	617,761
OH	5,235	5,718,433	13,345	9,925,721	2,594,242	10,449,166
OK	1,508	3,744,745	3,659	2,882,107	129,519	2,543,591
OR	1,385	1,535,744	2,781	2,435,654	308,628	2,055,684
PA	1,267	2,177,005	34,150	16,403,311	3,386,002	11,538,094
RI	981	1,190,461	1,751	1,401,444	292,492	944,712
SC	1,385	2,171,359	2,288	1,318,968	107,111	2,590,516
SD	635	179,345	1,733	540,369	206,300	665,507
TN	611	1,840,463	3,802	2,805,170	381,790	3,913,696
TX	2,419	6,604,700	7,935	7,828,976	147,857	11,075,054
UT	225	97,047	1,763	593,555	251,600	1,040,408
VT	153	224,720	719	329,185	139,562	444,330
VA	5,040	3,420,272	8,538	5,426,833	630,292	4,595,273
WA	883	1,981,644	3,818	3,870,572	603,140	3,366,234
WV	721	765,721	1,857	1,001,972	324,843	1,741,268
WI	789	2,402,685	7,936	5,737,875	1,271,831	4,345,611
WY	258	71,578	835	308,554	106,028	332,416
Total	75,700	113,871,072	348,420	235,409,256	36,617,791	200,520,781

PF of 40 or greater, while others are deficient. Basements are also distributed unevenly. There are 5.5 people per home basement nationally, but this varies from 65 per basement in Florida to 3 per home basement in South Dakota. The location of the shelter is as important as its existence.

The public shelters listed in the NSS file are concentrated in large structures in urban areas. National totals of shelter facilities and available spaces in each NSS data base and home basements are shown in Table D.5. Elimination of all aboveground spaces reduces the total available shelter capacity from about 349 million spaces to less than 83 million, to about 24% of the total capacity. This process, however, reduces the facilities to 76% of the total facilities. Rejection of the aboveground and low PF (<40) in areas considered to be at risk of blast damage reduced the total available spaces to 138.6 million, a loss of 60% of the total spaces. These data show that much of the shelter (throughout the nation) is aboveground, and that many of the aboveground, low-PF spaces are located in risk areas, where better shelter would be needed.

The shelters in the National Fallout Shelter Survey inventory in 1972 were sampled and surveyed by Tolman et al. (1973). The facilities investigated were limited to those containing 50 or more spaces, and the sampling procedure was statistically biased toward large shelters; that is, a facility with a large number of shelter spaces had a higher probability of selection than a facility with a small number of spaces. Over one-third of the spaces (35.5%) were estimated to be in basements or sub-basements; this number excluded spaces in special facilities. Our data, based on computations using the entire NSS data base, minus sensitive facilities, found that 23.6% of the 1976 NSS shelter spaces were belowground, as may be calculated from data in Table D.5.

Tolman's study also concluded that over 21 million spaces could have been added to the 1972 public shelter inventory if ventilation were improved. The study estimated that almost 11 million of these could have been adequately ventilated using only Kearny pumps (Kearny, 1972) and minor building modification.

Table D.5. Nationwide Comparison of NSS Facilities and Spaces in 50 States (December 1976)

	Number of Facilities		Total	Number of Spaces		Total
	PF < 40	PF ≥ 40	Facilities	PF < 40	PF ≥ 40	Spaces
Entire NSS	75,700	348,420	424,120	113,871,072	235,409,256	349,280,328
Risk-nonrisk NSS	65,729	275,869	341,598	36,838,229	101,734,884	138,573,113
Risk	0	213,496	213,496	0	58,018,348	58,018,348
Nonrisk	65,729	62,373	128,102	36,838,229	43,716,536	80,554,765
Belowground NSS	53,818	270,166	323,984	9,742,570	72,796,105	82,538,675
Home Basements[a]	36,647,406	0	36,647,406[b]	183,237,030	0	183,237,030

[a] All home basements given average PF of 25. Many can be upgraded during crisis period. Total of spaces based on 5 people per basement.

[b] Includes Puerto Rico.

D.6 Conclusions

Possible fallout shelters, both in facilities available to the general public and in home basements, were located and identified. We find much of the public shelter located in very large facilities. Neither NSS shelters nor home basements are evenly distributed across the nation. The question of how much of this potential fallout shelter is actually accessible to the residential population must now be approached.

Appendix E

SHELTER POSTURES

APPENDIX E: SHELTER POSTURES

E.1 Introduction

Once the population and the number and description of the available shelter spaces were known, the pattern of use had to be estimated. Several factors in shelter use were identified; these included the following: travel distance, type of shelter preferred, number of occupants per home basement, protection value of shelter, and the action of civil authorities. All three shelter availability data sets were examined through variation of some of these parameters. The analytical process is described in this appendix.

E.2 Factors in Shelter Use

E.2.1 Allowed travel distance.

We assumed that residents of an SLA would have access to all shelters in that SLA. The shelter postures were created for a residential population using community shelters; no relocation of population was involved. For some people, for example, those located near the border of an SLA, shelters in a neighboring SLA might be closer to their homes and should not be excluded. It was then necessary to specify a distance to the available shelter in some manner in order to include spaces in adjacent SLAs while restricting the travel distance sufficiently to maintain a community shelter posture.

The distance that community residents can travel depends on the attack assumptions, the amount of advance warning, and the travel means available. If the warning were based on a confirmed ICBM launch, only about 25 min or less would be available until some areas are affected by blast. This would limit a walking population in risk areas to shelters within 1 mile (1.6 km) or 2 from their homes. These distances are consistent with those found in other studies of shelter travel and arrival times (Haaland and Heath, 1972).

A travel radius was defined to specify the distance traveled to shelters in terms of the distance between centroids of SLAs. A travel radius of 1.0 mile (1.6 km) means that all shelters within SLAs which have centroids within a distance of 1.0 mile from the centroid of the

SLA in which the people live are considered available to those persons. To study the effects of this distance, the travel radius was varied from 0.5 mile (0.8 km) to 5.0 miles (8.0 km).

E.2.2 Shelter preference.

When both home basements and NSS shelters are available, some residents may prefer a home basement to a public shelter. This preference is hard to predict, since it may be the result of a quick, irrational decision.

The choice of the type of shelter may be based on the public perception of the shelter conditions at each place. More than half of the participants in a limited survey by Warner and Christiansen (1972) saw living conditions at the public shelters as chaotic, bad, or crowded, but a majority thought food, water, medical help, and leadership would be available there. Most did not know where the nearest shelter was, what fallout protection their basement offered, and had no emergency supplies stored.

Despite their lack of preparation, a slight majority of the respondents (Warner and Christiansen, 1972) preferred shelter in a home basement. Other surveys quoted by Nehnevajsa (1976) show a slight preference for public shelter. In any case, it seems there will always be a sizable percentage preferring home basements. In our study this percentage was varied from 0 to 100%.

E.2.3 Basement density.

The number of people that can be sheltered in a home basement varies with the size and nature of the basement. Sociological factors such as kinship, friendship, and desire for security and privacy may also influence home basement use. Nehnevajsa (1976) has assumed that only 10% of homes with basements are considered "suitable" as shelter, and that only 50 to 80% of the residents would be willing to participate in a home-sharing program. We placed no such restrictions on the use of basements. However, we found that under the Community Shelter Plan only about 3% of the home basements would be required for sharing (Appendix C).

Five people per basement were chosen as a minimum sharing population. There are slightly less than 5.5 people per home basement, averaged nationwide (200 million people in 36 million basements). In 1976 there were 2.9 people per household, or 3.4 people per family (U.S. Bureau of the Census, 1977). Five people could be a family, an extended family, or two families. The average number of occupants per home with a basement was estimated to be approximately three in Appendix C.

The highest basement density chosen was 50. This was obtained from using Nehnevajsa's (1976) approximation of 1000 ft^2 for the average nationwide basement area. Half of this area was assumed to be suitable for shelter; hence, 50 people could be sheltered using DCPA's standard of 10 ft^2 per person. Fifty people would probably include strangers or acquaintances, in addition to family, friends, or neighbors. Supplemental ventilation such as that provided by the Kearny air pump (Kearny, 1972) would be necessary for this number of people to survive for any period greater than a few hours in a single home basement during certain periods of the year.

Several surveys, reviewed by Warner and Christiansen (1972), suggest that willingness to share a basement does not extend to an unlimited number of strangers. While they may take in strangers in a real emergency, people want to have a choice in this matter and will favor friends and relatives as sharees. Nehnevajsa (1976) assumes that five households, on the average, would be sheltered in each basement. He concludes that no specific packing factor for home basements should be set, since 95% of his respondents agree to put as many people in their basement as it will hold if it is a matter of life or death.

E.2.4 Protection value of shelter.

If there are equally attractive choices available, the public may choose what they feel is the best shelter. Their idea of "best" may differ from the actual protection factor (PF) estimates and may reflect their opinion as to probable targets. The spaces in public shelters have been identified by PFs; this information could be distributed to the general public. The importance of shelter quality in determining use will also depend on the public perception of the degree of threat. If the fallout threat is thought to be light, the comfort of a "poorer" shelter may prove more appealing.

The PF of NSS shelters ranges from 15 to 2000, as listed in Table D.1. Home basements were assumed to have an average PF of 25 based on the assumption that various measures to upgrade the protection factor would be taken during a crisis period preceding the arrival of fallout (Department of Defense, 1976).

E.2.5 Attitudes and actions of authorities.

Instructions and information can be the most important factor in shelter use. Any information the public receives prior to the attack will influence their choice of shelter. Specific information on the attack will also influence their choice of shelter. Specific information on the best-shielded public shelters or instructions on upgrading basements may change the decision. Local emergency plans may be the dominant factor. In an emergency, most people will follow instructions from civil authorities if they feel those in positions of leadership are qualified and can be trusted.

The actions of the authorities may vary throughout the country; this factor is impossible to use as a parameter in postulating national shelter postures. It may, however, determine which shelter posture will be assumed.

E.3 Shelter Assignment

For each of the three shelter availability bases, shelter assignment was made by SLA within an RSAC area. To complete this procedure, each SLA was examined twice. The first attempt dealt only with the residential SLA, while the second considered excess spaces nearby.

In the first allocation, people who prefer home basements are assigned to home basements within the SLA in which they live. Basements are filled at the chosen density, that is, 5, 10, 20, or 50 people per basement, until either the basement spaces are exhausted or the chosen fraction of the total population of the SLA has been assigned. The remaining people are placed in NSS shelters in the same SLA, filling the spaces with the highest PF first. If there are not enough spaces in the NSS shelters, people can then fill in remaining home basements in the SLA. This procedure is followed for each SLA within an RSAC. Excess spaces, their type, and the number of unsheltered people are recorded.

On the second search through each SLA, shelter for the unsheltered people is sought in nearby SLAs. The number of accessible SLAs is reduced by specifying the maximum travel radius between the centroids of the two SLAs. Assignment is made to excess spaces in NSS shelters (highest PF first). When these are filled, the unsheltered people are placed in remaining home basements within the specified distance.

The assignment process can be illustrated with Fig. E.1. A map of part of a city (Detroit, Michigan) with NSS shelters and SLA centroids is shown. Since there are no NSS shelters in the center SLA, the population of that SLA would be placed in home basements within the same SLA until they are filled to the preset density, such as five people per basement. If the acceptable travel radius were 0.5 mile (0.8 km), the remaining unsheltered people from the center SLA could be placed in extra spaces in any of the four NSS shelters in the three adjoining SLAs with centroids inside the first circle. If the NSS spaces had previously been exhausted, remaining home basement spaces may be filled in those three SLAs. If the travel radius were doubled, extra spaces in any of the allowable 17 SLAs containing 19 public shelters could be used for unsheltered people from the home SLA.

E.4 Shelter Postures

Sums of people in each type of shelter and each protection category were obtained for each SLA, RSAC, state, and the nation. The total population unsheltered was also accumulated. The effects of changing the maximum number of people allowed in a home basement, increasing the distance outside the residence SLA in which shelter might be sought, and altering the percentage of people who prefer home basement shelters were also studied. A shelter profile was created for each set of conditions to show the distribution of the population among the three shelter categories--NSS shelters, home basements, and unsheltered. This was done for each of the three NSS data bases.

The profiles resulting from the variation of the percentage preferring home basement shelters when the travel distance was 1 mile (1.6 km) are shown in Figs. E.2, E.3, and E.4. A detailed description of the

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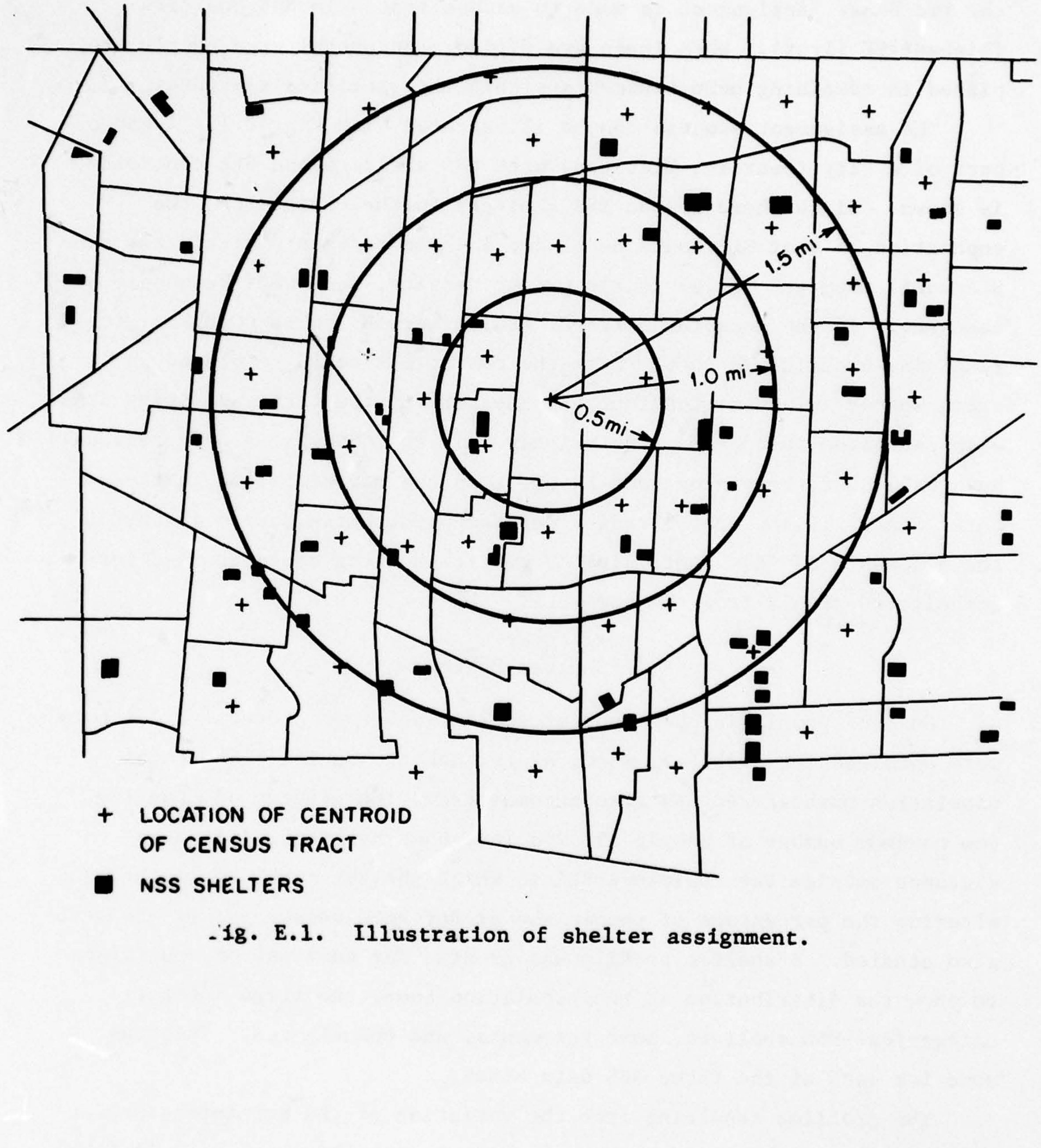

.ig. E.1. Illustration of shelter assignment.

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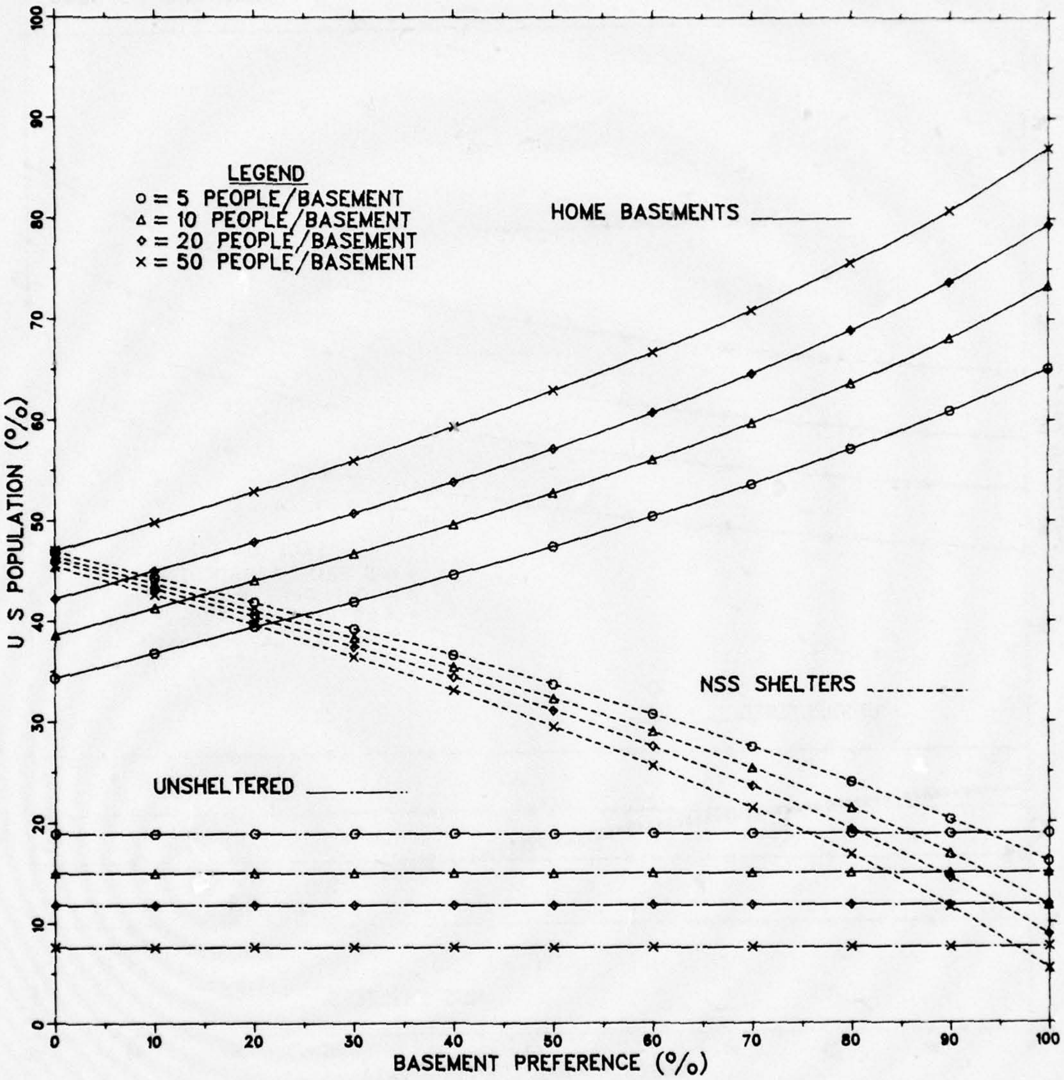

Fig. E.2. Profile of sheltered population prepared using all NSS shelters and home basements, but limited to a 1.0-mile travel radius.

ORNL-DWG 78-5585

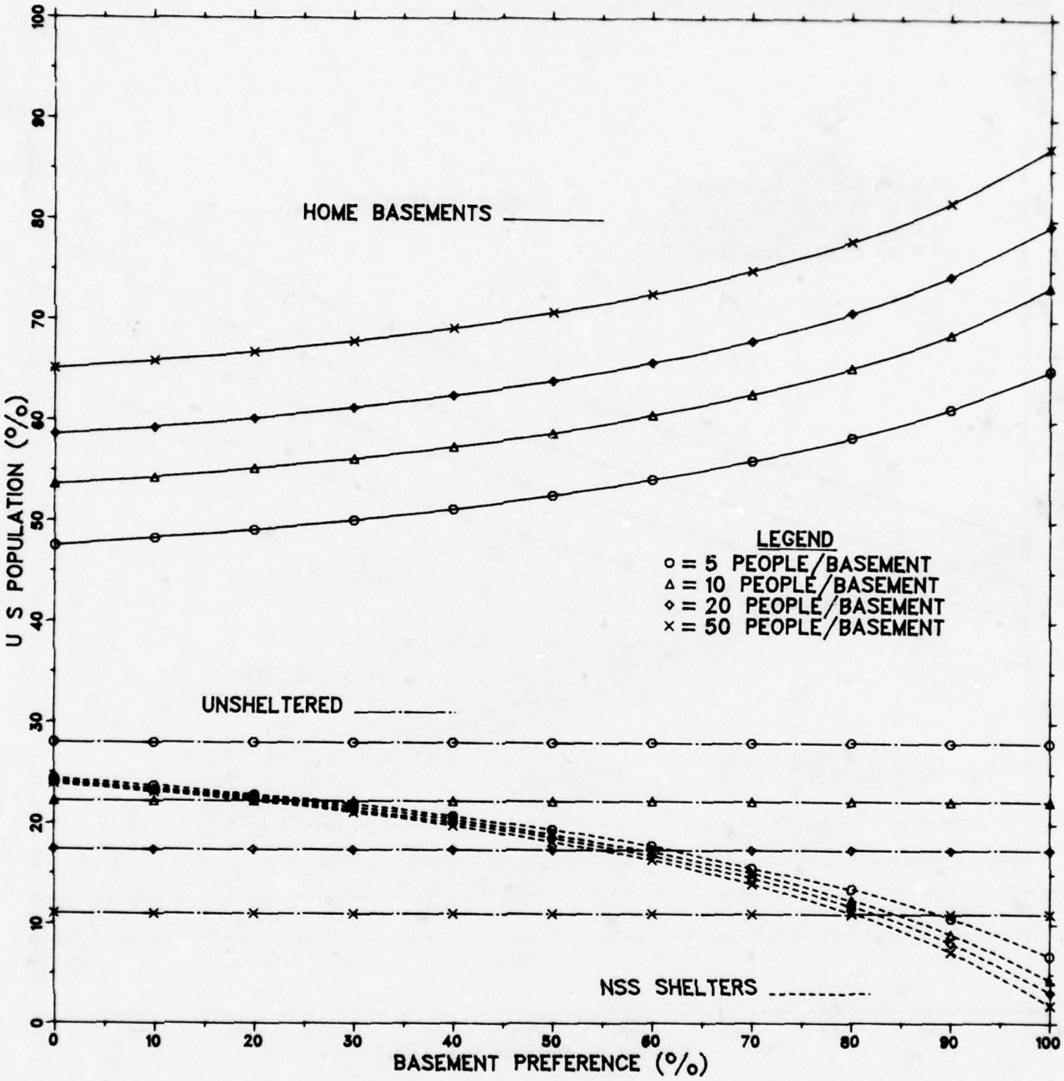

Fig. E.3. Profile of sheltered population prepared using only belowground NSS shelters and home basements, but limited to 1.0-mile travel radius.

ORNL-DWG 78-5587

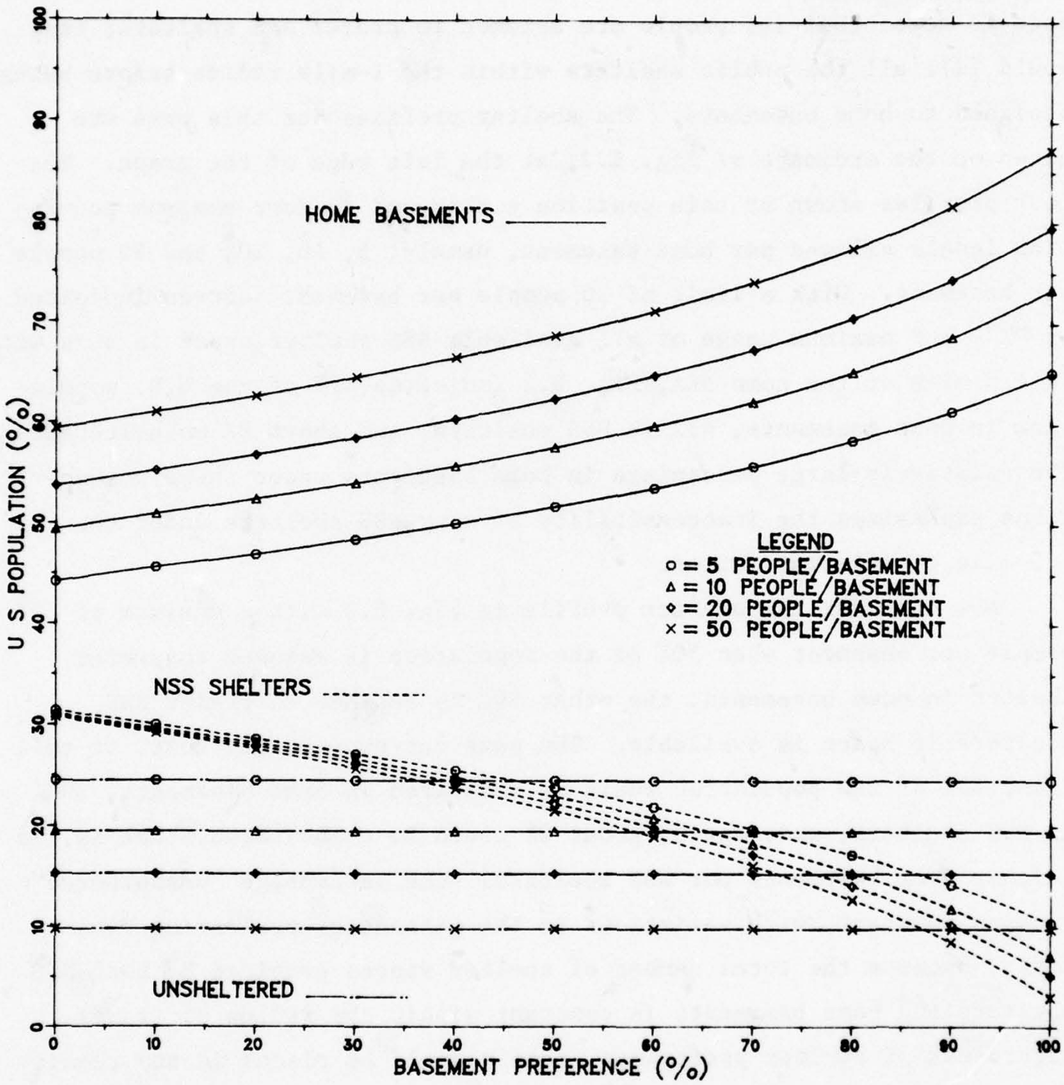

Fig. E.4. Profile of sheltered population prepared using risk-modified NSS data base and home basements, but limited to 1.0-mile travel radius.

results displayed in Fig. E.2, where the entire NSS shelter data base was used, will serve to clarify the other two figures.

In Fig. E.2, consider the shelter profile when the basement preference is zero; that is, people are assumed to prefer NSS shelters; they would fill all the public shelters within the 1-mile radius before being assigned to home basements. The shelter profiles for this case are given on the ordinate of Fig. E.2, at the left edge of the graph. The four profiles shown at this position correspond to four maximum population levels allowed per home basement, namely, 5, 10, 20, and 50 people per basement. With a limit of 50 people per basement (curves indicated by "X") and maximum usage of all available NSS shelter space in SLAs within 1.0 mile of the home SLA, Fig. E.2 indicates 47% of the U.S. population in home basements, 45% in NSS shelters, and about 8% unsheltered. The relatively large percentage in home basements under these assumptions emphasizes the inaccessibility of many NSS shelters under the 1.0-mile travel restriction.

Now consider the shelter profile in Fig. E.2 with a maximum of 50 people per basement when 50% of the population is assumed to prefer shelter in home basements; the other 50% is assumed to prefer NSS shelters if space is available. The same curves indicate that, in this case, 63% of the population would be sheltered in home basements, 29% in NSS shelters, and, again, about 8% would be unsheltered, that is, in neither home basements nor NSS shelters. The percentage "unsheltered" remains constant, with variations in the percentage preferring basements, because the total number of shelter spaces provided by both NSS shelters and home basements is constant within the radius of travel. Regardless of shelter preference, people would be placed in any remaining spaces in NSS shelters or home basements before being designated as "unsheltered."

Finally, when the basement preference is 100%, the curves in Fig. E.2 for the case of 50 people allowed per basement indicate a shelter profile of 87% in home basements, 5% in NSS shelters, and about 8% unsheltered, as before.

In a similar manner, shelter profiles for 5, 10, and 20 people allowed per basement can be read from Figs. E.2, E.3, and E.4 for any percentage of the population who might be assumed to prefer home basements as shelters.

In Fig. E.3, only belowground NSS spaces are used. The number forced to use home basements (0% basement preference) has increased, but the percentage using home basements when they are the shelter of choice (100% basement preference) is about the same. The decreased number of NSS spaces available causes a lowering of the number of NSS occupants, with a corresponding increase in population left unsheltered.

The risk-modified NSS data base produces shelter postures (Fig. E.4) similar to those of the other two data bases. Since fewer public shelter spaces have been eliminated than in Fig. E.3, the percentage of the population in each shelter category generally falls between the other two postures. Home basement usage approached the same value in all cases as the percentage preferring home basements increases.

Even at 50 people per basement, part of the population remains unsheltered when the 1.0-mile (1.6 km) travel radius is used. Table E.1 shows the RSACs in which, under these restrictions, more than 50, 100, or 200 people would need to be placed in each home basement in order to shelter everyone. In other words, there will probably be people with no readily available shelter in these RSACs. The average number of people per basement necessary to absorb the unsheltered population over the entire state when all accessible NSS spaces are used is also shown. These averages are all less than 50 per basement. This supports Nehnevajsa's (1976) contention: "It is of little help to a planner to know how many basements there are in the nation, in a state, in a county (parish) or in a city . . . the planner must determine the actual location of each basement."

Tables E.2 and E.3 present similar data when the travel radius is increased to 2.0 miles (3.2 km) and 5.0 miles (8.0 km). These increases reduce the number of counties with insufficient shelter spaces (basement density >50/basement) from 503 in the case of a 1.0-mile travel radius, to 299 in the case of a 5.0-mile travel radius. An increase in travel radius will have a significant effect only in those highly populated areas where the SLAs are closely packed. If the distance to the nearest SLA centroid were greater than 5.0 miles, changing the allowed travel

Table E.1. Basement Loading per State with Maximum Usage of NSS Shelters (BP = 0.0%)

Approximate Distance to Shelter: 1.0 Mile

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density >50/BSMT	>100/BSMT	>200/BSMT	Average Number per Basement over Entire State
AL	1,454,905	3,227,386	1,949,628	16	2	0	11.1
AK	77,204	322,111	219,766	3	2	1	2.5
AZ	823,603	1,628,294	937,020	3	0	0	13.1
AR	644,435	1,824,858	1,277,788	33	20	2	15.7
CA	8,051,344	24,950,593	11,639,166	4	0	0	10.1
CO	996,030	2,321,118	1,196,459	1	0	0	2.6
CT	1,652,298	4,781,041	1,353,371	0	0	0	1.6
DE	278,572	758,603	264,434	0	0	0	2.1
DC	723,007	6,427,781	27,686	0	0	0	0.1
FL	3,664,797	10,805,336	3,010,039	45	26	10	29.4
GA	2,699,463	8,673,588	1,850,428	66	39	11	5.8
HI	352,037	913,779	414,988	1	0	0	5.4
ID	290,039	359,352	422,528	0	0	0	2.4
IL	3,687,709	10,371,703	7,209,664	0	0	0	2.6
IN	2,304,693	5,701,891	2,785,530	0	0	0	2.8
IA	1,212,883	1,655,045	1,608,323	0	0	0	1.9

Table E.1. (continued)

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density >50/BSMT	>100/BSMT	>200/BSMT	Average Number per Basement Over Entire State
KS	1,425,538	2,725,207	790,318	0	0	0	1.7
KY	1,290,663	3,404,207	1,881,061	0	0	0	4.2
LA	1,324,683	2,373,046	2,304,797	60	48	15	36.3
ME	588,860	900,789	403,188	0	0	0	1.5
MD	1,825,842	5,393,660	2,032,647	0	0	0	2.2
MA	3,047,213	8,884,009	2,581,947	0	0	0	1.5
MI	3,197,704	7,606,607	5,553,949	0	0	0	2.5
MN	2,408,383	6,100,559	1,284,027	0	0	0	1.2
MS	887,664	1,162,834	1,328,419	55	20	2	24.7
MO	2,081,608	6,102,148	2,568,061	1	0	0	2.3
MT	399,534	694,036	294,875	0	0	0	1.5
NE	684,862	1,142,752	752,856	0	0	0	1.8
NV	267,421	1,704,907	221,317	0	0	0	3.1
NH	466,059	857,687	271,622	0	0	0	1.3
NJ	3,554,581	7,891,211	3,561,019	0	0	0	1.9
NM	511,417	946,507	502,910	4	0	0	8.1
NY	10,439,398	35,320,096	7,453,972	0	0	0	1.4
NC	2,365,577	5,306,756	2,627,531	28	12	1	6.7
ND	329,514	452,799	288,247	0	0	0	1.4

Table E.1. (continued)

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density			Average Number per Basement Over Entire State
				>50/BSMT	>100/BSMT	>200/BSMT	
OH	4,826,044	10,753,411	5,623,122	0	0	0	2.2
OK	1,540,499	5,083,614	1,003,092	6	1	0	7.7
OR	852,668	3,113,406	1,203,016	0	0	0	3.9
PA	5,446,442	13,120,565	6,091,652	0	0	0	1.8
RI	680,287	1,884,214	264,425	0	0	0	0.9
SC	1,314,042	2,139,468	1,276,474	17	7	0	11.9
SD	349,750	361,408	315,757	0	0	0	1.5
TN	1,385,167	3,005,524	2,528,529	4	1	0	6.6
TX	4,019,396	10,276,045	7,055,658	151	85	13	47.7
UT	614,998	1,544,360	425,410	0	0	0	1.7
VT	242,235	311,399	202,095	0	0	0	1.4
VA	2,202,774	6,451,247	2,392,499	5	2	0	3.8
WA	1,313,004	4,501,459	2,053,230	0	0	0	3.4
WV	645,001	1,120,362	1,096,267	0	0	0	3.4
WI	2,348,650	5,789,355	1,996,961	0	0	0	1.6
WY	170,726	209,371	161,690	0	0	0	1.5
Total	93,961,323	253,357,504	106,559,458				2.9

Table E.2. Basement Loading per State with Maximum Usage of NSS Shelters
(BP = 0.0%)

Approximate Distance to Shelter: 2.0 Miles

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density			Average Number per Basement Over Entire State
				>50/BSMT	>100/BSMT	>200/BSMT	
AL	1,666,939	3,015,352	1,737,594	15	2	0	9.9
AK	90,343	308,972	206,627	3	2	1	2.4
AZ	1,082,883	1,369,014	677,740	2	0	0	9.5
AR	741,391	1,727,902	1,180,832	31	19	2	14.5
CA	9,969,956	23,031,981	9,720,554	4	0	0	8.4
CO	999,299	2,317,849	1,193,190	1	0	0	2.6
CT	1,652,927	4,780,412	1,352,742	0	0	0	1.6
DE	286,876	750,299	256,130	0	0	0	2.1
DC	723,007	6,427,781	27,686	0	0	0	0.1
FL	4,264,357	10,205,776	2,410,479	42	25	10	23.5
GA	2,860,641	8,512,510	1,689,350	65	39	11	5.3
HI	416,488	849,328	350,537	0	0	0	4.6
ID	290,039	359,352	422,528	0	0	0	2.4
IL	3,711,417	10,347,995	7,185,956	0	0	0	2.5
IN	2,385,535	5,621,049	2,704,688	0	0	0	2.7

Table E.2. (continued)

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density			Average Number per Basement Over Entire State
				>50/BSMT	>100/BSMT	>200/BSMT	
KS	1,443,143	2,707,602	772,713	0	0	0	1.6
KY	1,311,949	3,382,921	1,859,775	0	0	0	4.1
LA	1,634,279	2,063,450	1,995,201	60	44	15	31.4
ME	589,020	900,629	403,028	0	0	0	1.5
MD	1,826,868	5,392,634	2,031,621	0	0	0	2.2
MA	3,047,277	8,883,945	2,581,883	0	0	0	1.5
MI	3,225,252	7,579,059	5,526,401	0	0	0	2.5
MN	2,408,488	6,100,454	1,283,922	0	0	0	1.2
MS	993,555	1,056,943	1,222,528	53	19	2	22.7
MO	2,113,866	6,069,890	2,535,803	1	0	0	2.3
MT	399,534	694,036	294,875	0	0	0	1.5
NE	685,185	1,142,429	752,533	0	0	0	1.8
NV	329,393	1,642,935	159,345	0	0	0	2.3
NH	466059	857,687	271,622	0	0	0	1.3
NJ	3,568,225	7,877,567	3,547,375	0	0	0	1.9
NM	569,763	888,161	444,564	4	0	0	7.2
NY	10,441,743	35,317,751	7,451,627	0	0	0	1.4
NC	2,504,953	5,167,380	2,488,155	28	12	1	6.3
ND	329,514	452,799	288,247	0	0	0	1.4

Table E.2. (continued)

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density			Average Number per Basement Over Entire State
				>50/BSMT	>100/BSMT	>200/BSMT	
OH	4,849,164	10,730,291	5,600,002	0	0	0	2.2
OK	1,679,818	4,944,295	863,773	6	1	0	6.7
OR	905,758	3,060,316	1,149,926	0	0	0	3.7
PA	5,454,753	13,112,254	6,083,341	0	0	0	1.8
RI	682,974	1,881,527	261,738	0	0	0	0.9
SC	1,404,464	2,049,046	1,186,052	16	7	0	11.1
SD	355,296	355,862	310,211	0	0	0	1.5
TN	1,545,674	2,845,017	2,368,022	4	1	0	6.2
TX	5,137,630	9,157,811	5,937,424	142	77	13	40.2
UT	618,136	1,541,222	422,272	0	0	0	1.7
VT	242,235	311,399	202,095	0	0	0	1.4
VA	2,383,561	6,270,460	2,211,712	5	2	0	3.5
WA	1,356,844	4,457,619	2,009,390	0	0	0	3.3
WV	653,428	1,111,935	1,087,840	0	0	0	3.3
WI	2,348,650	5,789,355	1,996,961	0	0	0	1.6
WY	170,726	209,371	161,690	0	0	0	1.5
Total	100,032,240	247,286,587	100,488,541				2.7

Table E.3. Basement Loading per State with Maximum Usage of NSS Shelters
(BP = 0.0%)

Approximate Distance to Shelter: 5.0 Miles

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density			Average Number per Basement Over Entire State
				>50/BSMT	>100/BSMT	>200/BSMT	
AL	1,890,854	2,791,437	1,513,679	13	2	0	8.6
AK	100,183	299,132	196,787	3	2	1	2.3
AZ	1,242,392	1,209,505	518,231	2	0	0	7.2
AK	837,274	1,632,019	1,084,949	31	19	2	13.3
CA	12,216,513	20,785,424	7,473,997	3	0	0	6.5
CO	1,013,270	2,303,878	1,179,219	1	0	0	2.5
CT	1,653,871	4,779,468	1,351,798	0	0	0	1.6
DE	286,522	750,653	256,484	0	0	0	2.1
DC	723,007	6,427,781	27,686	0	0	0	0.1
FL	5,298,410	9,171,723	1,376,426	38	24	10	13.4
GA	3,100,450	8,272,701	1,449,541	63	39	11	4.6
HI	482,273	783,543	284,752	0	0	0	3.7
ID	292,504	356,887	420,063	0	0	0	2.4
IL	3,774,133	10,285,279	7,123,240	0	0	0	2.5
IN	2,450,247	5,556,337	2,639,976	0	0	0	2.7
IA	1,216,616	1,651,312	1,604,590	0	0	0	1.9

Table E.3. (continued)

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density >50/BSMT	>100/BSMT	>200/BSMT	Average Number per Basement Over Entire State
KS	1,464,070	2,686,675	751,786	0	0	0	1.6
KY	1,383,580	3,311,290	1,788,144	0	0	0	4.0
LA	1,889,947	1,807,782	1,739,533	57	42	15	27.4
ME	589,020	900,629	403,028	0	0	0	1.5
MD	1,857,850	5,361,652	2,000,639	0	0	0	2.2
MA	3,051,163	8,880,059	2,577,997	0	0	0	1.5
MI	3,256,103	7,548,208	5,495,550	0	0	0	2.5
MN	2,408,861	6,100,081	1,283,549	0	0	0	1.2
MS	1,028,507	1,021,991	1,187,576	51	18	2	22.1
MO	2,122,406	6,061,350	2,527,263	1	0	0	2.3
MT	400,479	693,091	293,930	0	0	0	1.5
NE	685,223	1,142,391	752,495	0	0	0	1.8
NL	280,103	1,692,225	208,635	0	0	0	3.0
NH	466,059	857,687	271,622	0	0	0	1.3
NJ	3,596,551	7,849,241	3,519,049	0	0	0	1.9
NM	592,344	865,580	421,983	3	0	0	6.8
NY	10,446,150	35,313,344	7,447,220	0	0	0	1.4
NC	2,682,669	4,989,664	2,310,439	26	11	1	5.9
ND	329,514	452,799	288,247	0	0	0	1.4

Table E.3. (continued)

State	Population in NSS Shelters	Number of Unused NSS Spaces	Population Forced into Basements	Number of RSACs with Basement Density >50/BSMT	>100/BSMT	>200/BSMT	Average Number per Basement Over Entire State
OH	4,885,417	10,694,038	5,563,749	0	0	0	2.1
OK	1,894,411	4,729,702	649,180	6	1	0	5.0
OR	1,038,789	2,927,285	1,016,895	0	0	0	3.3
PA	5,481,849	13,085,158	6,056,245	0	0	0	1.8
RI	680,287	1,884,214	264,425	0	0	0	0.9
SC	1,622,385	1,831,125	968,131	13	7	0	9.0
SD	352,465	358,693	313,042	0	0	0	1.5
TN	1,755,320	2,635,371	2,158,376	4	1	0	5.7
TX	6,846,466	7,448,975	4,228,588	133	73	12	28.6
UT	629,289	1,530,069	411,119	0	0	0	1.6
VT	242,235	311,399	202,095	0	0	0	1.4
VA	2,579,253	6,074,768	2,016,020	5	2	0	3.2
WA	1,514,341	4,300,122	1,851,893	0	0	0	3.1
WV	658,999	1,106,364	1,082,269	0	0	0	3.3
WI	2,348,899	5,789,106	1,996,712	0	0	0	1.6
WY	170,975	209,122	161,441	0	0	0	1.5
Total	107,810,498	239,508,329	92,710,283				2.5

radius from 1.0 mile to 5.0 miles would have no effect. A detailed investigation of all 299 RSACs in which the basement density is shown as greater than 50 per basement in Table E.3 would be necessary in order to determine whether people in these RSACs could be sheltered in neighboring RSACs. If not, it may be necessary for people in these areas to construct expedient shelters (Cristy, 1973; Kearny, 1976).

When the home basement population density is set at five and the travel distance is varied, the shelter posture curves can look quite different. In Fig. E.5 one finds little change in home basement usage when the travel distance is increased from 1.0 mile (1.6 km) to 5.0 miles (8.0 km). The increase in people in NSS shelters and the corresponding decrease in the number of people unsheltered are more pronounced. The distribution of home basements approximates the residential population distribution much better than the NSS shelters do. Increasing the travel distance by a factor of 5 adds less than 4% of the more than 347 million NSS shelter spaces to the available pool.

Only the belowground NSS spaces are considered in Fig. E.6. The differences in NSS use are less dependent on travel radius now, since there are fewer NSS spaces to consider. Overall usage is lower than in the preceding graph for the same reason. Home basement shelterees are more numerous and only slightly more dependent on travel distance. A larger proportion of the population will be placed in basements farther from their homes, since fewer NSS spaces in neighboring SLAs are available for the overflow of the residential SLA.

Shelter postures prepared under the same assumptions from the risk-modified NSS shelter data base are shown in Fig. E.7. Use of each type of shelter and dependence on travel radius fall between the two previous graphs. Home basement use is again very similar as the preference for the private shelters increases.

If everyone prefers public shelter, the home basements are used at five per basement, and travel is limited to 1.0 mile (1.6 km), the distribution of shelters used when all NSS shelters are available (not risk-modified) is shown in Table E.4. Shelters are categorized here by occupants instead of rated number of spaces. We find the number of shelters fairly evenly distributed among the use categories. Still,

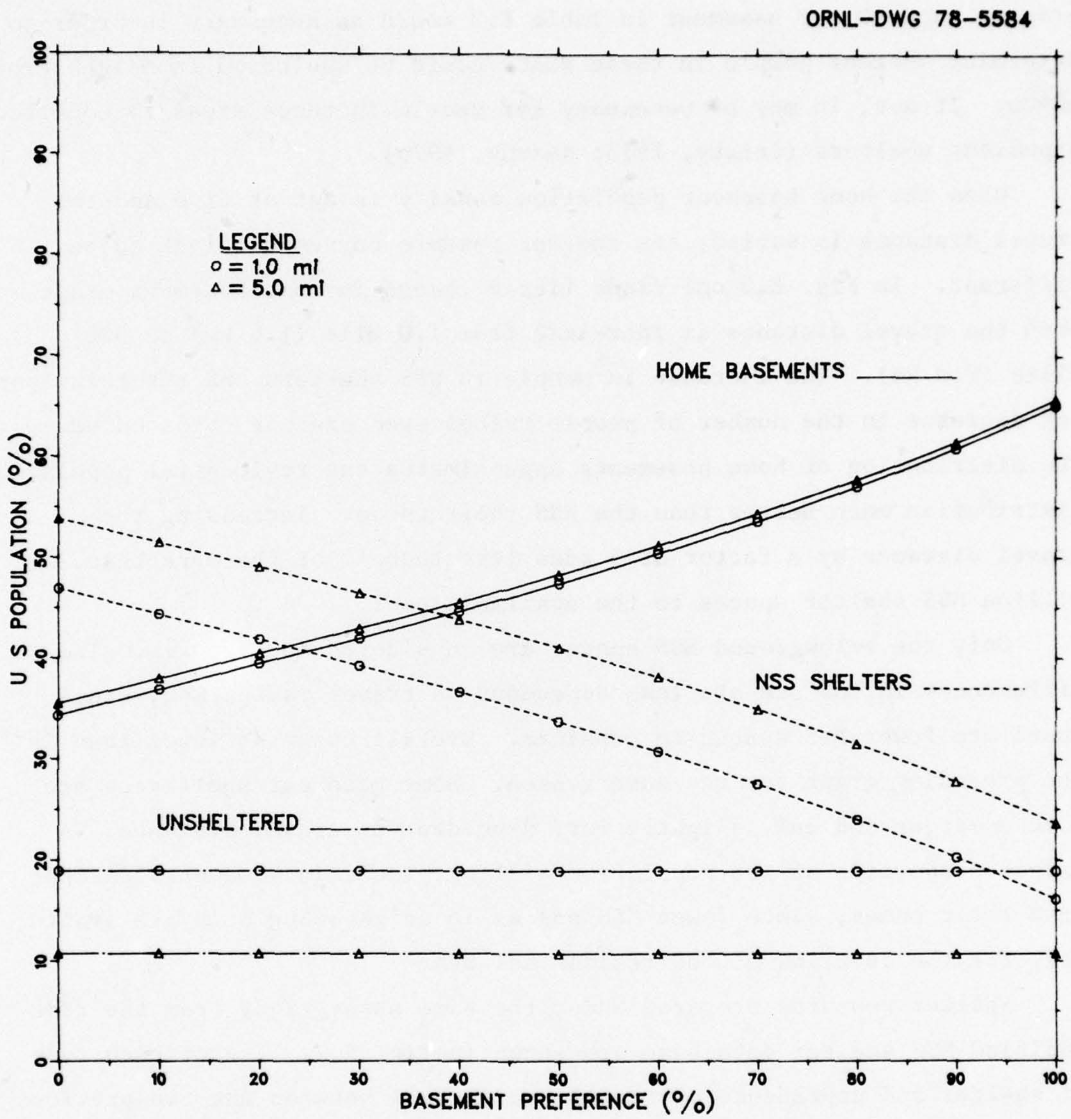

Fig. E.5. Profile of sheltered population prepared using all NSS shelters and home basements, but with a limit of five people per home basement.

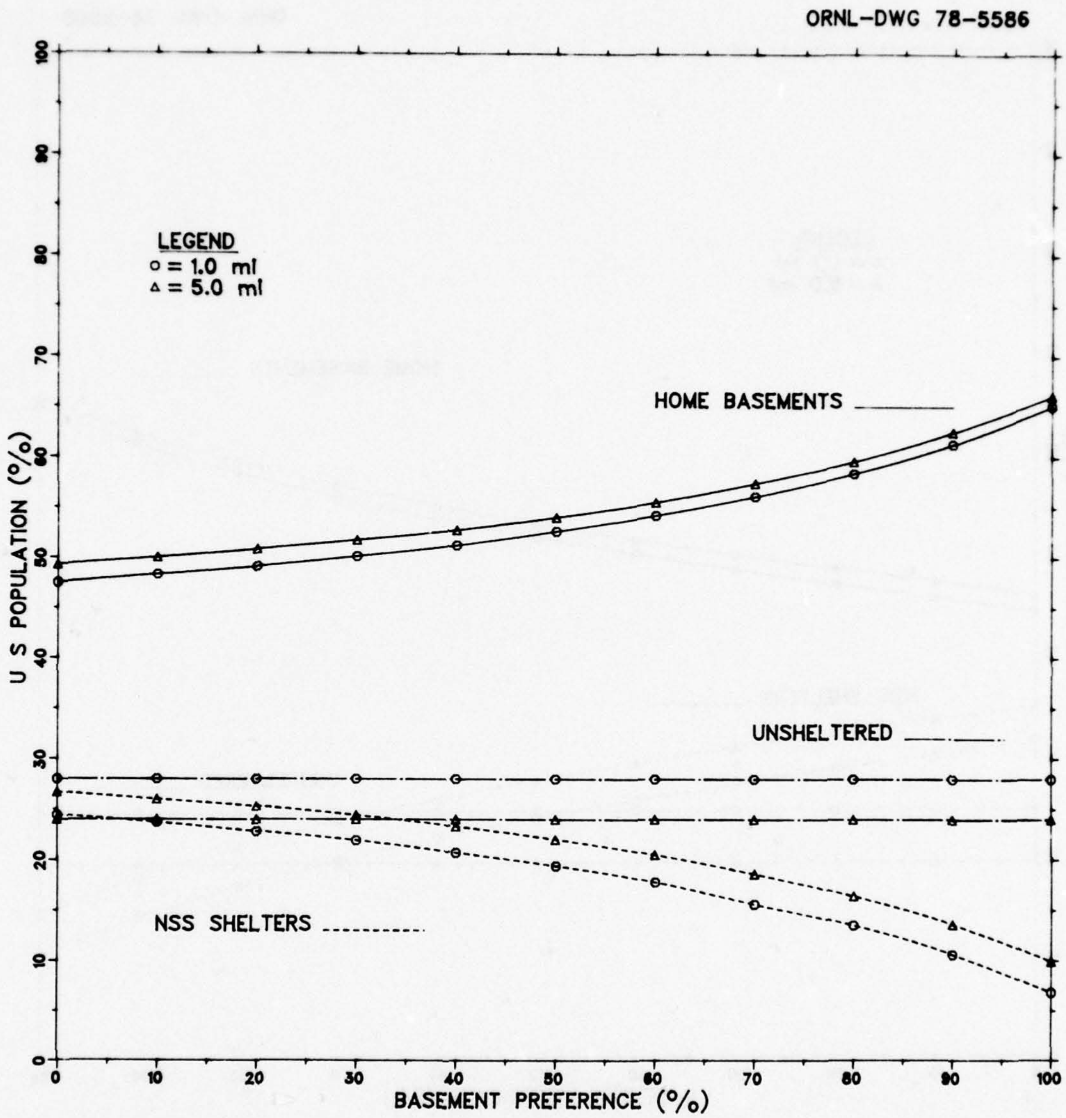

Fig. E.6. Profile of sheltered population prepared using only belowground NSS shelters and home basements, but with a limit of five people per home basement.

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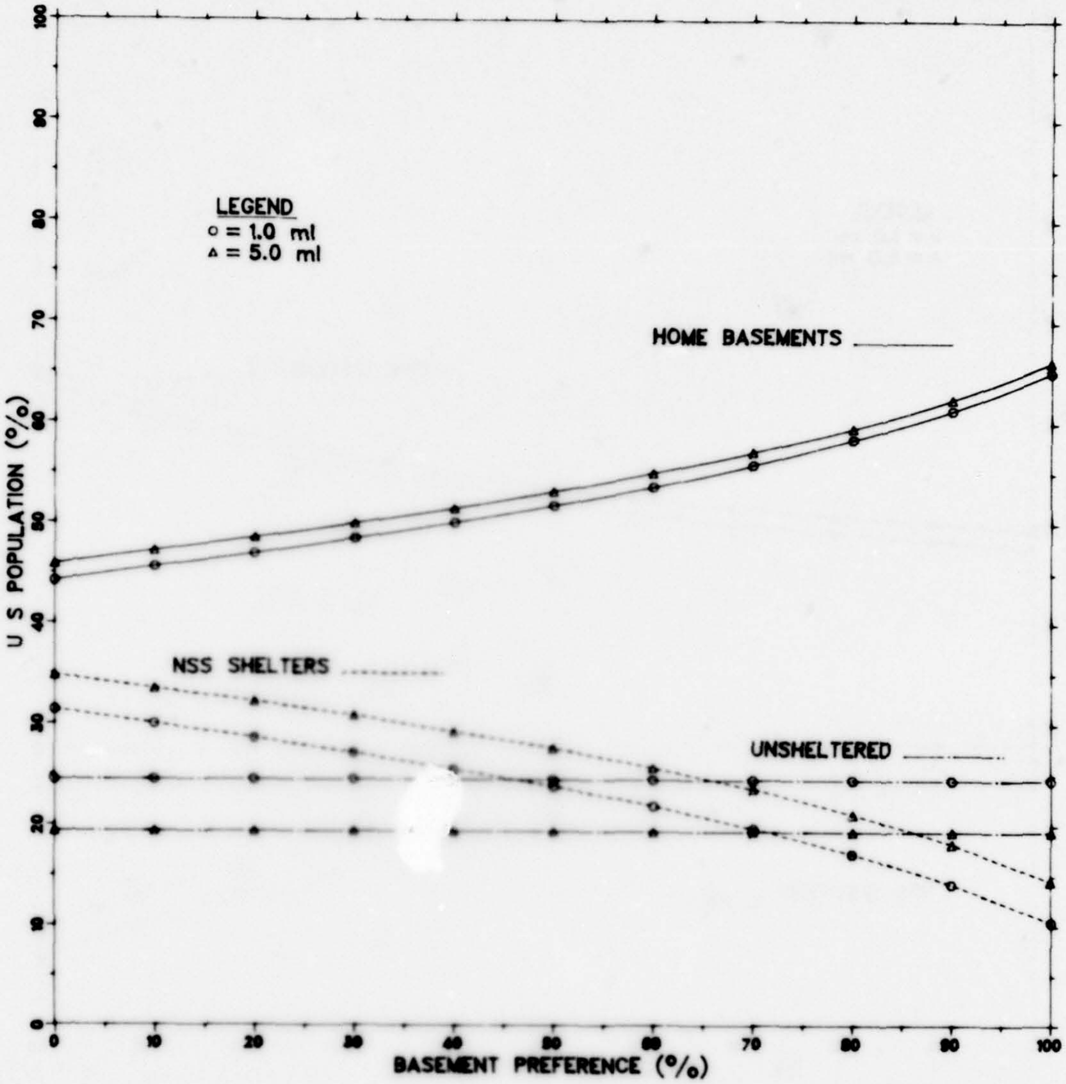

Fig. E.7. Profile of sheltered population prepared using risk-modified NSS data base and home basements, but with a limit of five people per home basement.

Table E.4. NSS Shelter Occupancy with 1.0-mile Travel Radius

Number of Occupants per Shelter	Number of Shelters Occupied	Percent of Total Occupied Shelters	Number of Spaces Occupied	Percent of Total Occupied Spaces	Average Number of Occupants per Shelter
1-19	20,025	12.0	280,162	0.3	14.0
20-49	27,057	16.3	942,591	1.0	34.8
50-99	25,792	15.5	1,913,722	2.0	74.2
100-199	25,657	15.4	3,761,680	4.0	146.6
200-499	30,500	18.3	9,910,331	10.6	324.9
500-999	16,838	10.1	11,902,740	12.7	860.2
1000+	20,524	12.4	65,250,097	69.4	3179.2
Total	166,393	100.0	93,961,323	100.0	

almost 70% of the people are found in the larger shelters. When the travel limitation is raised to 5.0 miles (8.0 km), 14 million additional spaces are occupied, and 12 million of these are located in shelters having an occupancy of over 1000 persons (Table E.5). The average number of occupants in the category of largest shelters exceeds 3000.

When the risk-modified NSS shelter data base is used, everyone prefers public shelter, home basements are used at five per basement, and travel is limited to 1.0 mile (1.6 km), the distribution of shelter occupancies is that shown previously in Table 3.6. Modification of the risk-area NSS shelter data base reduced the total occupancy of 94.0 million (Table E.4) to 62.9 million, from 27% to 18% of the total number of 347 million NSS spaces. The percent of total occupied spaces in the largest shelters (i.e., >1000 occupants) in both risk and nonrisk areas has been reduced from 69.4% (Table E.4) to 48.6%. The total number of shelters used has increased from 166,393 (Table E.4) to 212,776 (Table 3.6, sum of risk and nonrisk) because many more small shelters are used in the risk area when the large aboveground shelters are removed from the data base.

The protection factor profile for the nation was shown in Table 3.7. It has been assumed that people in homes with no basements are able to improvise protection which would give them an average PF of 5. Two-thirds of the risk area population of 124 million, that is, 82 million, would require shelter in home basements, with many packed at 50 people per basement.

The disparities in the number of shelter occupants introduce some shelter management problems. Very large shelters will be impossible to administer unless they are highly organized, well-supported, and make full use of the skills, training, and talents of the occupants. The small shelters may require less organization, but the resources of the shelterees will be severely limited by the small population sample. More effort per person will be required for these shelters. It would be more efficient if medium-sized shelters could be developed where necessary to replace shelters in the smallest use categories. These shelters could also help reduce the sheltered population in the biggest facilities to a more manageable figure.

Table E.5. NSS Shelter Occupancy with 5.0-mile Travel Radius

Number of Occupants per Shelter	Number of Shelters Occupied	Percent of Total Occupied Shelters	Number of Spaces Occupied	Percent of Total Occupied Spaces	Average Number of Occupants per Shelter
1-19	20,441	11.7	285,797	0.3	14.0
20-49	27,890	16.0	974,489	0.9	34.9
50-99	26,557	15.2	1,973,404	1.8	74.3
100-199	26,498	15.2	3,889,126	3.6	146.8
200-499	31,649	18.2	10,294,172	9.5	325.3
500-999	17,921	10.3	12,695,485	11.8	708.4
1000+	23,281	13.4	77,698,025	72.1	3337.4
Total	174,237	100.0	107,810,498	100.0	

E.5 Conclusion

Because of the sociological and situational factors discussed, it is impossible to predict accurately the pattern of shelter usage. Well-organized community plans and an informed public could reduce the guesswork for some counties, but some aspects will always be uncontrollable.

With current shelter inventories, some fraction of the people will never find shelter near their residence. The NSS spaces are not always located where they are needed. Use of home basements (even with 50 people per basement) does not appear to be the total solution. Efforts should be made to locate or construct more public shelters in areas that are deficient. Expedient shelters may, in some areas, become a necessary consideration in protecting the U.S. population from fallout.

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ABSTRACT

Based on a detailed computer simulation of a Community Shelter Plan posture, it is estimated that 3.4 million new dosimeters and 1.4 million new ratemeters would be required for radiological defense. To maintain dose records for all shelter occupants, 18.1 million new dosimeters and 1.4 million new ratemeters would be required.

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REPORT NO: ORNL-5371 CLASSIFICATION: Unclassified

AUTHOR(S): Carsten M. Haaland and Kathy S. Gant

TITLE: Instrumentation Requirements for Radiological Defense of the U.S. Population in Community Shelters

Please affix amended page 48 to your copy(ies) of ORNL-5371 Section 4.3. The amended page was prepared on a gum label for your convenience.

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Sincerely,

J L Langford

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the NSS shelter requirements, producing a total of 3.4 million dosimeters, 1.3 million chargers, and 1.4 million survey meters at a total cost of $75 million dollars, as summarized in Table 4.3.

Table 4.3. Minimum Instrument Requirements for Shelters, without Supplementary Instrumentation (Allocation B)

Instruments	Estimated Requirement (million $)	Estimated Cost per Instrument ($)	Total Estimated Cost (million $)
Survey meters	1.4	20	28
Dosimeters	3.4	10	34
Chargers[a]	1.3	10	13

[a]Fiber-optics dosimeters would not require chargers.

Although this apportionment may provide adequate instrumentation to guarantee equal radiation exposure, there will be insufficient instrumentation to provide a record of dose for more than a small percentage of the sheltered population.

4.4 Instruments Required for Maintaining Dose Records (Allocation C)

In this final case, dosimeters will be allocated according to the scheme in Table 3.7, based on the organization of shelter occupants into units. In order to provide a fairly accurate estimation of dose for all shelter occupants, the number of people per unit should be specified by shelter management to be from 7 to 12 members, depending on shelter configuration and variability of PF and in accordance with the Shelter Management Textbook (Department of Defense, 1967). An approximate average of ten people per unit was used in the preparation of Table 4.4. In shelters with large rooms and uniform PF, the number per unit could