AD-A159 719

Final Report

MULTI-HAZARD SHELTER INCENTIVE PROGRAMS

Prepared for:

FEDERAL EMERGENCY MANAGEMENT AGENCY
Washington, D. C. 20472

Contract: EMW-84-C-1570
Work Unit No. 1616B

September 1985

20030116002

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A159 719	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Multi-Hazard Shelter Incentive Programs		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Walmer E. Strope, John F. Devaney, Richard K. Laurino, and Seymour Wengrovitz		8. CONTRACT OR GRANT NUMBER(s) EMW-84-C-1570
9. PERFORMING ORGANIZATION NAME AND ADDRESS Center for Planning and Research, Inc. 560 San Antonio Road, Suite 105 Palo Alto, California 94306		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1616B
11. CONTROLLING OFFICE NAME AND ADDRESS Federal Emergency Management Agency Washington, D.C. 20472		12. REPORT DATE September 1985
		13. NUMBER OF PAGES 232
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

391236

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

With contributions by James O. Buchanan, Francis Dresch, Hanford M. Edsall, H. L. Murphy, James E. Powers, and George N. Sisson.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Multi-hazard shelter, all-effects shelter, fallout shelter, building construction, shelter costs, Strategic Defense Initiative, tax incentives, protective construction, disasters, civil defense.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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FEMA Review Notice

This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency.

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ACKNOWLEDGEMENTS

The authors were assisted in important ways by other members of the Center staff and its consultants. Dr. James O. Buchanan performed the INR analysis of Appendix A. James E. Powers, Hanford M. Edsall, and Francis W. Dresch contributed to the analysis of incentives. H. L. Murphy revised the all-effects shelter costs and designed the parking garage door. He and George N. Sisson reviewed design procedures and types and costs of closures. Research assistance and support were provided by Norman Furth and Ruth Parker.

Substantive assistance was provided by the staff of the Building Permit Branch, Construction Statistics Division of the Bureau of the Census and the Office of Policy Development and Program Evaluation of the Department of Housing and Urban Development. Our special thanks go to Mr. James Blakely, Arkansas administrator for HUD Solar Energy and Energy conservation Bank Programs, Mr. Robert Smiley, Alabama Building Commission, and Mr. Lawrence Bowden, Deputy Director, Alabama Emergency Management Agency. Dr. B. Wayne Blanchard, FEMA Project Officer, provided excellent support.

DETACHABLE SUMMARY

This report contains the objectives and concepts of multi-hazard shelter incentive programs, describes the data sources and methodology used to estimate the probable performance and cost of eleven alternative shelter incentive programs, and presents conclusions and recommendations.

The basic concept of these programs is to incorporate shelter protection into the design of new buildings and other construction either by various direct and indirect payment incentives or by both. Prior approaches of this type both in the U.S. and in foreign countries are reviewed to expand and define the concept. Proprietary construction and building permit data are reviewed and reconciled to establish an "average year" rate of slantable construction. These data are further refined to exhibit the characteristics of slantable construction inside and outside urbanized areas. A working assumption is made that all-effects shelter would be specified in urbanized areas and fallout shelter elsewhere. The results are exhibited in Tables S.1 and S.2.

Shelter design methodology and shelter costs as of 1983 have been reviewed. Balanced designs for all nuclear weapons effects at 15, 20, and 30 psi blast overpressure from a 1-Megaton surface burst and for PF 40 and PF 100 fallout protection are considered before settling on 30 psi and PF 100 for costing purposes. Complete shelter standards are provided in an appendix to the report. Current unit costs for all-effects shelter are estimated at from $23 to $30 per square foot, varying inversely with shelter size. Costs for PF 100 fallout protection in new building basements is estimated at $5 per square foot. These costs are additional costs over normal project costs.

A variety of incentive options are analyzed for application to a shelter program. Eleven alternative shelter incentive programs are presented that demonstrate the options. Five programs are mandatory in nature and the remainder are voluntary. One program, No. 7, is the only candidate program designed to make participation in the program a profitable venture. The eleven programs are rank-ordered in Table S.3 first by estimated shelter yield and, for identical yields, by program cost. A preferred program is proposed that consists of Programs 1 and 10 for the first two years to gain cost experience, followed by Program 7 for four years.

TABLE S.1

ANNUAL CONSTRUCTION AND SHELTER IN URBANIZED AREAS

BUILDING CATEGORY	VALUATION (Million $)	PROJECTS (Number)	AVERAGE COST (000 $)	FLOOR AREA (Million Sq. Ft.)	OCCUPANCY ASSUMPTION (Sq. Ft. per Person)	POTENTIAL SHELTER (000s)
Office Bldgs	$ 9,930	13,340	744	137	100	1,370
Commercial	7,300	28,860	253	193	60	3,220
Manufacturing	2,920	7,340	398	54	100	540
Educational	3,260	5,640	582	39	80	490
Hospitals & Health	4,670	2,770	1,686	44	190	230
Other Nonresidential	2,920	8,680	336	39	100	390
TOTAL NONRESIDENTIAL	31,020	66,630	470	506	81	6,240
One-Family Developments	27,400	5,600	4,891	693	650	1,060
Multi-Family Housing	12,310	25,360	486	322	100	3,220
Nonhousekeeping Residential	2,920	2,290	1,275	42	100	420
TOTAL RESIDENTIAL	42,630	33,250	1,282	1,057	225	4,700
ALL BUILDINGS	$73,650	99,880	737	1,563	143	10,940

TABLE S.2

ANNUAL CONSTRUCTION AND SHELTER OUTSIDE URBANIZED AREAS

BUILDING CATEGORY	VALUATION (Million $)	PROJECTS (Number)	AVERAGE COST (000 $)	FLOOR AREA (Million Sq. Ft.)	OCCUPANCY ASSUMPTION (Sq. Ft. per Person)	POTENTIAL SHELTER (000s)
Office Buildings	$ 3,670	10,480	350	51	100	510
Commercial	2,700	22,685	119	72	60	1,200
Manufacturing	1,080	5,775	187	20	100	200
Educational	1,220	4,425	276	14	80	180
Hospitals & Health	1,730	2,170	797	16	190	80
Other NonResidential	1,030	6,820	158	15	100	150
TOTAL NONRESIDENTIAL	11,480	52,355	219	188	81	2,320
One-Family Developments	10,130	4,400	2,302	252	650	390
Multi-Family Housing	4,560	19,920	229	119	100	1,190
Nonhousekeeping Residential	1,080	1,800	600	15	100	150
TOTAL RESIDENTIAL	15,770	26,120	604	386	223	1,730
ALL BUILDINGS	$27,250	78,475	347	574	142	4,050

TABLE S.3

COMPARISON OF ALTERNATIVE PROGRAMS

Program		Annual Yield (Spaces)		Annual Program Cost		Cost per Space	
No.	Title	All-Effects (millions)	Fallout (millions)	GNP ($ bill.)	Budget ($bill.)	GNP ($)	Budget ($)
7.	Flat Incentive Payment*	28.58	11.10	9.24	9.22	233	232
5.	Mandatory Plus NonProfit Subsidy	11.52	2.55	3.00	1.33	213	95
8.	Grant Plus Loan Subsidy*	11.52	2.55	3.03	3.01	215	214
9.	Loan and Loan Subsidy*	11.52	2.55	3.03	3.01	215	214
11.	Public Sector Grant Plus Tax Credit*	11.52	2.55	3.15	3.13	224	223
4.	Mandatory With Subsidy	9.17	1.76	2.58	1.30	236	119
2.	Mandatory Shelter in All Bldgs.	7.57	1.76	2.15	0.16	230	17
3.	Mandatory Excluding Small Res.	6.53	1.42	1.85	0.16	233	20
10.	Public Sector Grant*	5.92	1.44	1.58	1.56	214	212
6.	Public Housing Qualification*	1.49	0.37	0.43	0.16	243	90
1.	Mandatory in Federal Bldgs.	0.58	0.10	0.17	0.15	246	224

*Includes Program 1

SECTION I

INTRODUCTION TO PROGRAM CONCEPTS

1.1 Multi-Hazard Shelter

The Federal Emergency Management Agency (FEMA) is responsible for enhancing population preparedness against the entire range of peacetime and wartime hazards that pose potential threats to the lives of U.S. citizens. One of the most important protective measures is sheltering. Sheltering and evacuation are the two principal lifesaving measures that can be taken to enhance population preparedness.

FEMA publication CPG 1-34 identifies and describes 21 "most common" hazards.[1] They are:

Natural Hazards	Technological/Manmade Hazards
Avalanche	Attack (Nuclear or Conventional)
Drought	Civil Disorder
Earthquake	Dam Failure
Flood	Hazardous Materials Incident
Hurricane	Hazmat Transportation Incident
Landslide	Nuclear Facility Incident
Tornado	Power Failure
Tsunami	Subsidence
Volcano	Transportation Accident
Wildfire	Urban Fire
Winter Storm	

Some of these hazards are best protected against by sheltering; others by evacuation. Of course, hazards that impact without warning can be mitigated only by altering the normal environment so that hazards are less threatening to life. If we define "shelter" as a protective room or space, nearby or part but not all of the normal environment, then sheltering is the preferred measure against certain hazards, is suitable in certain circumstances for others, and is not considered appropriate for still others.

Multihazard shelter is believed to be the preferred lifesaving measure against the following common hazards:

Attack (Nuclear or Conventional)
Civil Disorder (Gunfire, Terrorist Threat)

Hazardous Materials Incident
High Winds (Hurricanes or Tornadoes)
Nuclear Facility Incident
Winter Storm

All of the above provide a basis for ample warning to seek shelter. Multihazard shelter can be designed to provide the necessary protection. Note that the present emphasis on evacuation around nuclear power plants is necessitated by a lack of multihazard shelter, not a preference for evacuation.

The following hazards on the FEMA list could be protected against by multihazard shelter under certain circumstances:

Earthquake (against aftershocks or if warning is achieved)
Flood (vertical evacuation in storm surge areas or by berming the ground floor to above flood stage)
Urban Fire (if evacuation is not feasible)

Multihazard shelter is not considered an appropriate lifesaving measure against such hazards as:

Avalanche Drought Dam Failure
Hazmat Transportation Incident
Landslide Power Failure Tsunami
Subsidence Volcano Wildfire
Transportation Accident

1.2 All-Effects Shelter

The provision of public shelter against common hazards has not been considered seriously in the United States, except for those associated with nuclear attack. At the individual family level, only shelters against tornadoes, called tornado cellars, have been widely adopted in certain mid-western States where tornadoes are especially prevalent. Tornado safety rules promulgated by the U.S. Department of Commerce[2] urge that the public "seek inside shelter, preferably in a tornado cellar, underground excavation, or a steel-framed or reinforced concrete building of substantial construction. Stay away from windows!" In enlarging on these instructions, the flyer goes on to recommend the interior parts of lower floors and basements of buildings as preferred shelter areas. These areas also are those offering the best available shelter in existing buildings against the effects of nuclear explosions.

Two kinds of nuclear attack shelters have been considered: (1) fallout shelters and (2) all-effects shelters. All-effects shelters are commonly known as "blast shelters." However, such shelters must offer protection not only against the air blast wave but also the other life-threatening nuclear weapons effects that may be present to varying degrees in the region affected by blast from a nuclear detonation. These other effects include ground shock, thermal radiation (heat), initial nuclear radiation (INR), fires (including the toxic gases produced by fires), and fallout. Hence, so-called blast shelters are more properly termed all-effects shelters. Fallout shelters, as the name implies, are intended to provide a degree of protection against nuclear radiation from fallout but not other weapons effects. To indicate the potential role of the two kinds of nuclear attack shelters, a brief review of nuclear weapons effects is provided below.

1.3 Review of Nuclear Weapons Effects[3]

The damaging effects of nuclear weapons, while similar in nature to ordinary explosives, are enormously greater and pose the added threat of radioactivity. In 1945, weapons in the 10-20 kiloton range (one kiloton is equivalent to 1,000 tons of TNT) were considered major strategic weapons. Since that time, weapons have been developed in the tens of megatons range (one megaton is one thousand kilotons). Only a few of these very large nuclear weapons remain deployed. Most current strategic missiles have been designed to deliver a number of warheads of smaller yield. Thus, warheads can be directed at a larger number of targets by the available missiles. Weapons carried by current missiles range from about 200 kilotons to one megaton. The close-in or direct effects of the largest of these weapons are summarized in Figure 1.1 and are discussed in terms of "immediate radiation effects" and "blast effects."

a. Immediate Radiation Effects. The release of a large amount of energy in a small space creates a very high temperature, that is, a "fire ball", which in turn leads to thermal radiation from the fireball as long as it is hot. This heat radiates outward at the speed of light. The amount of thermal energy arriving at any point is greatest on a clear day and may be reduced greatly by pollution haze, fog, and rain. Under conditions of good visibility, fires can be ignited in tinderlike materials and the skin of exposed people burned to beyond the 2-psi range shown in Figure 1.1. Because of buildings and other obstructions, the fireball of a surface detonation is shielded from much

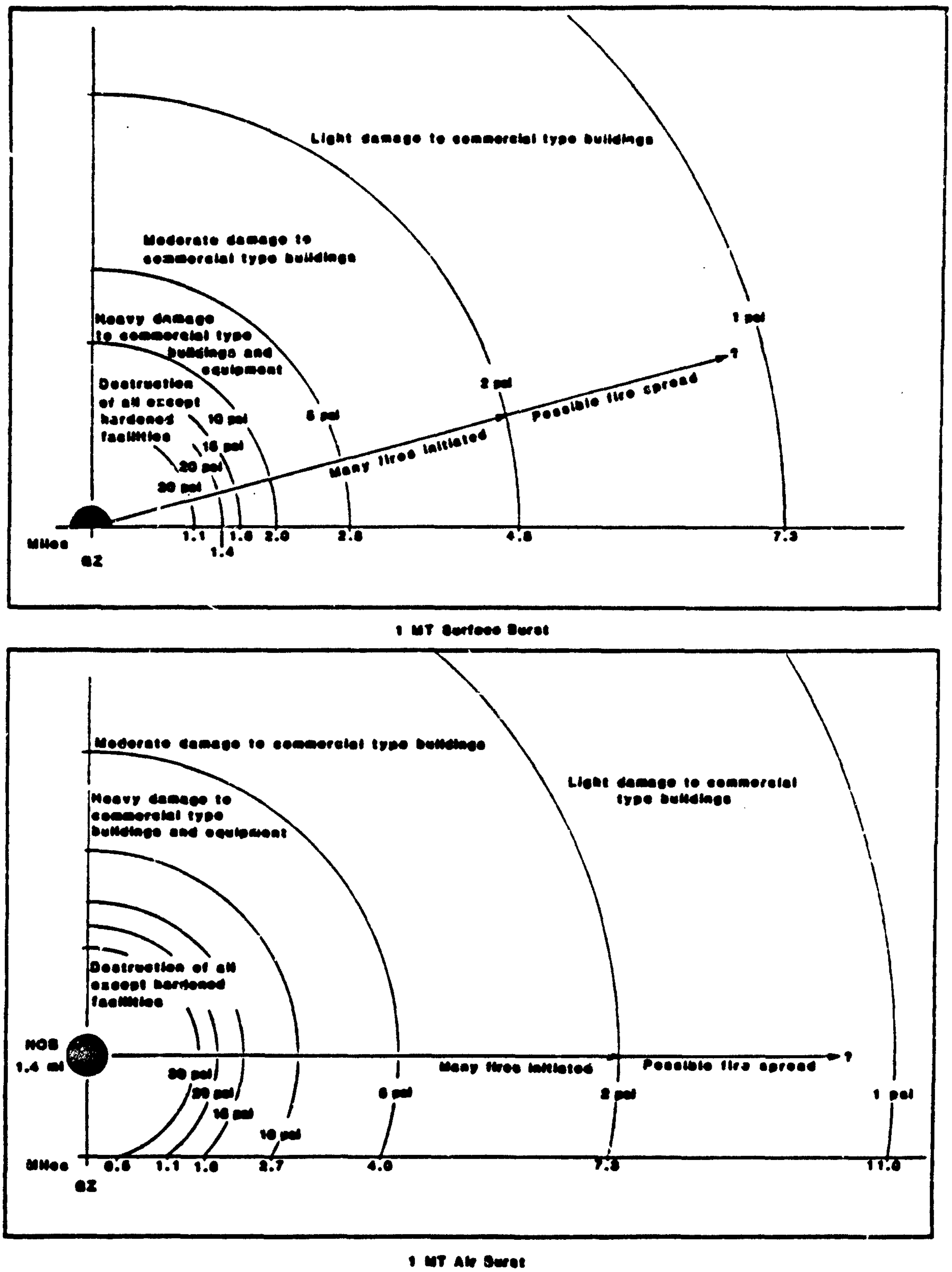

Figure 1.1. Direct Weapon Effects Region

of the surrounding area during its initial and hottest phase before it starts to rise.

Simultaneous with the heat flash, two other nearly instantaneous radiation effects occur, one hazardous to living things and the other damaging to electronic devices. The nuclear explosion releases a burst of highly penetrating radiation called "initial nuclear radiation (INR)" that can cause radiation injury and death to a distance of two miles or so. Protection against INR is an important consideration in the design of all-effects shelters. The detonation also produces an electromagentic pulse (EMP), sometimes called "radio-flash." The bulk of the EMP energy lies in the radio frequency spectrum ranging from powerline frequencies to radar frequencies. The energy is not high enough to injure living things but can be collected by antennas, wires, and other conductors so as to damage electrical and electronic equipment, especially those employing solid-state devices. In surface or near surface detonations, the range of EMP damage is about two to five miles from ground zero.

b. Blast Effects. In a nuclear detonation, the intense temperatures in the fireball also result in high pressure with the consequent formation of shock waves in the ground and in the air. The ground shock and earth movement can injure people in blast shelters and damage equipment close to the detonation. The air blast wave, which travels outward at a speed comparable to the speed of sound, can cause injuries and damage over a much larger areas.

The air blast wave consists first of a sudden increase in pressure followed by strong winds and a more gradual decrease in pressure. The overpressure lasts for one or two seconds, the winds for several seconds longer. The pressure wave is measured in pounds per square inch (psi). The wind (dynamic pressure) behind a 10-psi shock wave has a speed of about 280 miles per hour and can exert a force about five times as great as the most violent hurricane. At an overpressure of 30 psi, the winds are nearly 700 miles per hour. As the blast wave advances, it envelops and crushes buildings, tanks, and other hollow objects. Debris and noncrushable objects are carried along by the blast wind and distributed over considerable distances (hundreds of yards). The strength of the blast wave decreases rapidly as it moves outward, as shown in Figure 1.1. Beyond the distances shown for 1 psi, only minor damage, such as broken windows, will result.

Because all of the effects discussed above are operative within the area of significant blast damage, and, generally, within the area covered by at least 2 psi, it is common practice to use the blast overpressure as a marker in describing the other effects. Thus, ground shock can cause injury to people in blast shelters at overpressures above about 50 psi. The thermal radiation emitted by the fire ball is of sufficient intensity to ignite thin combustibles, such as paper, curtains, upholstery, and the like within the 2-psi region. The incendiary outcome, however, is quite uncertain because the following blast wave can extinguish incipient fires in the same region. Additionally, the blast wave can cause fires by damaging electrical circuits, fuel lines, and processing equipment with combustible liquids. Initial nuclear radiation is hazardous to people within two miles, including many in building basements. EMP from surface bursts can damage sensitive equipment within the 2-psi region. These effects, which are generally of significance in the damaged area, are collectively called the "direct effects" of nuclear detonations.

c. Fallout. If a nuclear detonation occurs at or near the ground, great quantities of earth and other materials are drawn upward to high altitudes with the mushroom cloud and mixed with the radioactive residues of the nuclear reaction. The radioactive particles, carried by the winds, fall to the ground over a period of many hours and over a wide area extending tens and often hundreds of miles beyond the region of direct effects. This phenomenon is known as "fallout". Where fallout occurs is determined by the wind currents and no location can be considered immune. Most of the area of direct effects also will experience fallout.

Fallout particles emit principally alpha, beta, and gamma radiation. The latter is the one of greatest hazard because it is highly penetrating. Gamma radiation emmitted from particles deposited over an area can contribute to radiation exposure. Gamma radiation can be detected and measured only with special instruments. The unit of measurement is the Roentgen (R).

The intensity of the gamma radiation from fallout is highest at early times, decreasing rapidly at first and then more slowly. A useful rule of thumb is that the intensity (in Roentgens per hour) decreases ten-fold with each seven-fold passage of time. Thus, a given intensity at seven hours after detonation will be only one-tenth as strong at two days (49 hours), one-hundredth at two weeks (7 times two days). In areas of heavy fallout, gamma radiation can be a hazard for many weeks. Because the body is able to repair some of the radiation injury, prolonged exposure is less injurious for a given dose tnan one received in a shorter interval. The consequences of radiation exposure are shown in the following table:

MEDICAL CARE WILL BE NEEDED BY	ACCUMULATED EXPOSURE (R) IN ONE WEEK	ONE MONTH	FOUR MONTHS
None	150	200	300
Some (5 percent may die)	250	350	500
Most (50 percent may die)	450	600	---

The foregoing description of fallout from a nuclear detonation has emphasized the condition of a surface or near-surface explosion. In a nuclear air burst (one in which the fireball does not touch the ground), debris is not present to lend weight to the radioactive residues produced, so they stay aloft for a long period of time. When they eventually return to earth, their radioactivity will have diminished to a relatively harmless level. However, air bursts have the capacity to extend the reach of relatively low overpressures at the expense of reduced overpressures near ground zero, as shown in Figure 1.1. Because ordinary buildings have little resistance to air blast, detonations well above the ground may be used against cities to maximize building damage with little fallout resulting.

Some nuclear detonations may occur at very high altitudes (above 20 miles) to increase greatly the area of damaging effects of EMP on electrical power systems, broadcast communcations, computers, and automated production facilities. Such high-altitude detonations can cause power outages and electronic damage over extremely large areas. Thus, both fallout from surface bursts and EMP from high-altitude bursts are effects that can be experienced far from the detonations themselves.

1.4 Best Available Shelter

It can be seen from the foregoing that fallout shelter would be needed virtually everywhere whereas all-effects shelter would be needed to save lives only in the immediate vicinity of nuclear detonations. Current multi-hazard shelter consists of mines, caves, tunnels, building basements, and the interior cores of aboveground parts of buildings. Such locations offer the best available shelter not only against nuclear weapons effects but also the other common hazards for which shelter is an appropriate protective measure. None of these refuges were created with the protective requirements of shelter in mind. Some (e.g., mines) offer excellent protection against a wide range of hazards. Most offer significant, although limited, protection. People are safer in best available shelter than they would be if more exposed to hazards. But taking shelter does not necessarily preclude injury or death if the best available shelter proves inadequate.

Ordinary dwellings do not offer substantial protection against nuclear weapons effects although fallout protection may be improvised in home basements. Larger buildings, especially basement areas, can offer very substantial fallout protection. For many years, FEMA and its predecessor agencies have routinely surveyed existing large buildings for fallout shelter. The National Facility Survey records now list about 400,000 buildings and other facilities throughout the country having nearly 250 million shelter spaces meeting the agency's minimum criterion for fallout protection. Unfortunately, these spaces are not well distributed with respect to the population, most being concentrated in the downtown areas of cities. Hence, there are many localities deficient in fallout shelter, especially in suburban and rural areas. Nonetheless, the NFS inventory forms the foundation for multihazard sheltering capability at this time.

The requirements for protection against the direct effects of nuclear weapons are quite demanding. Therefore, except where mines, caves, and tunnels are available, the best available all-effects shelter is not very good. In general, large buildings can withstand only relatively low levels of blast overpressure. When they do not collapse, the blast winds entering through shattered windows and doors can cause injuries and death. Moreover, the area where people might survive in best available shelter is vulnerable to ensuing fires and toxic gases. Thus, the possibility of injury and death results from multiple hazards. The evidence from Hiroshima and Nagasaki demonstrates that survival in reinforced concrete and masonry structures is possible but current analyses[4] suggest that survival is likely in best available shelter only in the 5-10 psi region. Figure 1.2 shows the distribution of the population with blast overpressure for the FEMA TR-82 nationwide attack. The curve shows that only about 30 to 40 percent of the population experiencing at least 2 psi

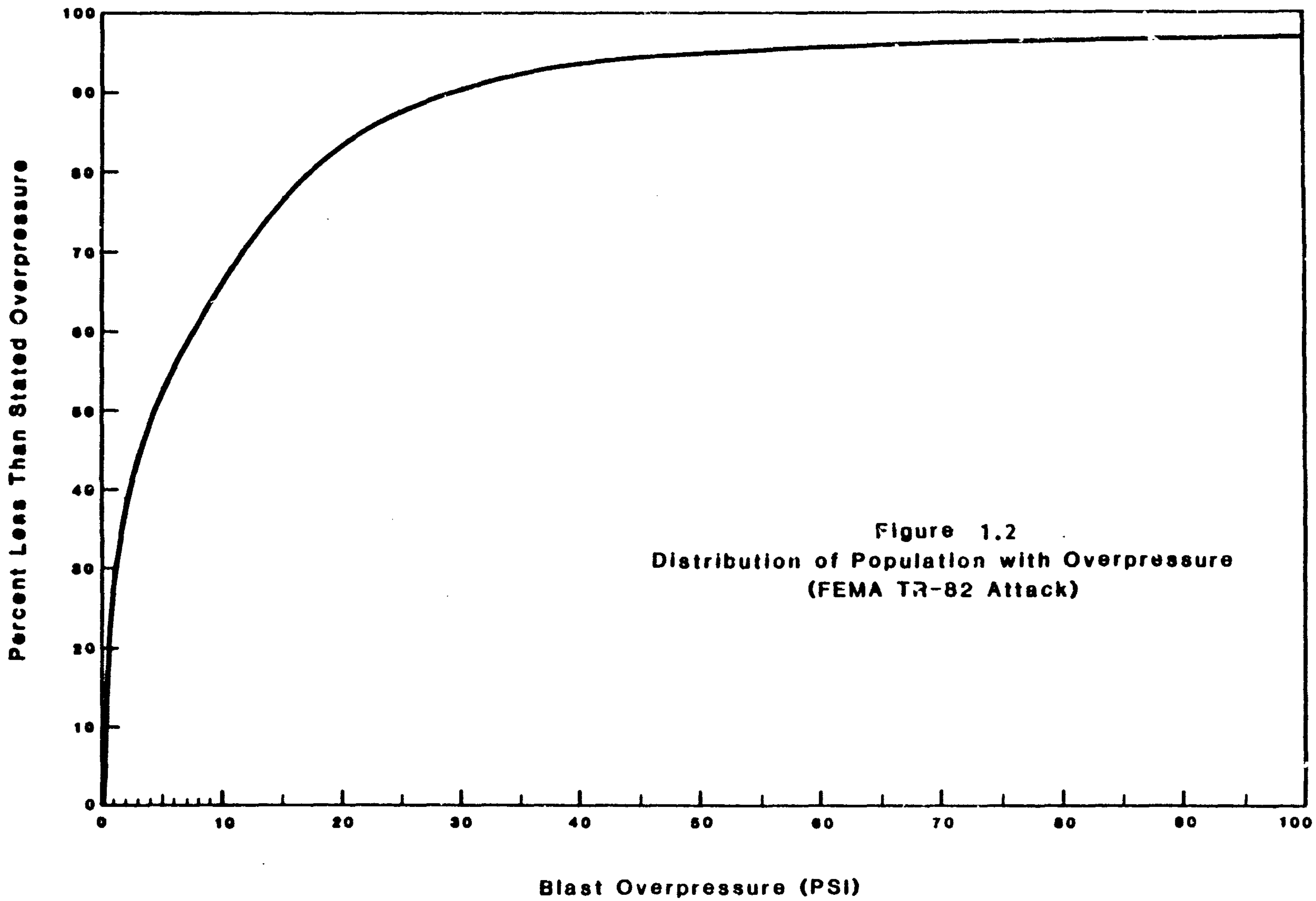

Figure 1.2
Distribution of Population with Overpressure
(FEMA TR-82 Attack)

were in the region of less than 5-10 psi. Thus, best available all-effects shelter would have been inadequate for most exposed to the hazard.

1.5 Crisis Relocation Planning

Recognition that best available shelter against the direct effects of nuclear weapons would not prevent heavy casualties if cities were targeted led to abandonment of a "fallout only" policy of population protection about 1975 in favor of a program to plan for the evacuation during a crisis of urban residents and others perceived to be at high risk of exposure to direct effects. This program, called Crisis Relocation Planning (CRP), was adopted by both the Carter and Reagan administrations in the form of decision memoranda and was written into law as Title V of the Civil Defense Act in 1980. Crisis relocation is an essential element of the civil defense program of the Soviet Union.[5] CRP has been considered the most appropriate response to a Soviet city evacuation. However, the CRP program has received criticism not only from those opposing all civil defense effort but also from more sympathetic observers.

It has been pointed out[6] that opinion surveys find that most Americans think that there will be too little time for city evacuation if a war threat occurs; this despite the fact that a Soviet city evacuation is expected to require a week or more. A public perception of evacuation urgency could jam outbound routes very quickly even though such routes would be perfectly adequate for an exodus over a several-day period. Other analysts have voiced concern over the lack of fallout shelter in reception areas. An influx of city dwellers would increase the demand for fallout shelter protection in rural areas where such protection already is in short supply. The planned solution to this problem is to create additional fallout shelter at the time of need by heaping earth against the side walls and on the roofs of ordinary buildings that otherwise would not provide sufficient fallout shielding, a crisis action program that is untried and technically controversial. In recent years, FEMA has reduced emphasis on CRP in favor of a broad approach to multi-hazard planning called the Integrated Emergency Management System (IEMS). The goal of IEMS is to develop a credible emergency management capability nationwide by integrating activities along functional lines at all levels of government and across all hazards, including nuclear attack.

1.6 Risk Areas

Adoption of crisis relocation as national policy required the government to identify the areas considered to be at high risk from the direct effects of nuclear weapons, should a war occur. Identification of risk areas also is needed with respect to sheltering, even best available shelter, in order to differentiate between locations needing all-effects shelter and those requiring fallout shelter only. Selection of risk areas is a policy decision. Hence, such areas are properly understood to be "policy areas," namely, areas within which it would be the Government's policy to deploy all-effects shelters, use best available shelter based on all-effects considerations, plan for evacuation of residents, or any combination of appropriate measures.

There are two basic approaches to the identification of potential risk areas. The first might be termed a "target-oriented" approach. Recognizing that his mission is population protection, the policy-maker directs his attention to his population centers, locations of high population density where many citizens are at risk. The Federal Civil Defense Administration's July 1953 publication[7], Target Areas for Civil Defense Purposes, states:

> "Atomic weapons are employed most effectively against centers of population and industry. Civil Defense is responsible for minimizing the effects of attacks upon people and property and since the resources available for this purpose are limited, priority must be accorded the major concentrations of population and industry.
>
> "The nation's Standard Metropolitan Areas comprise our major urban centers and as such provide a practical and established yardstick of urban concentration. Each of these areas, by definition, contains at least one city of 50,000 population or more, and includes all of the closely linked surrounding area.
>
> "For this reason, all Standard Metropolitan Areas are designated as Target Areas for Civil Defense Purposes. Those Standard Metropolitan Areas containing high concentrations of industry as well as population, that is, 40,000 or more manufacturing employees, are designated Critical Target Areas for Civil Defense Purposes."

Note that this definition of policy areas uses census data as its principal ingredient. In addition, all State capitals were listed as target areas whether or not they were in Standard Metropolitan Areas. In 1953, the list comprised 193 target areas, of which 70 were classed as critical target areas.

The second approach to the identification of risk areas may be termed the "attack-oriented" approach. Recognizing that a potential enemy has relatively well defined attack capabilties and less well defined objectives and priorities in mounting an attack, the policy-maker examines the attack possibilities and attempts to define risk in terms of the probability of experiencing nuclear weapon effects in any locality. The high risk areas defined by the Defense Civil Preparedness Agency (DCPA)[8] in 1975 were based on this approach. The document, known as TR-82, contains the following background:

"The following approach was used in designating high-risk areas:

1. Potential target values were developed using unclassified sources, indicated above, based on the following criteria listed in descending priority order:

   a. U.S. military installations.

   b. Military supporting industrial, transportation and logistics facilities.

   c. Other basic industries and facilities which contribute significantly to the maintenance of the U.S. economy.

   d. Population concentrations of 50,000 or greater (Bureau of the Census urbanized areas).

2. Based upon projections of Soviet capabilities (circa 1980) under existing Strategic Arms Limitation (SAL) agreements and U.S. target values, weapon assignments were developed considering U.S. active defenses, vulnerability and time sensitivity of targets, etc., with the objective of maximizing targets destroyed and minimizing weapons expended.

3. Probable targets were reviewed to eliminate isolated military and industrial facilities considered to be of marginal significance.

4. Based upon targets resulting from 3 above and weapon assignments, envelopes were plotted on State maps to depict areas subject to a 50% or greater probability of receiving blast overpressure of 2 psi or more. For this purpose it was assumed that all weapons were air burst; system reliability was 0.9, and Circular Error Probable (CEP) was 0.5 nautical miles. (Conservative assumptions used for planning purposes only to maximize direct effects.)"

Maps based on the foregoing procedure were reviewed with the State civil preparedness staffs for credibility. As a result of this review, 14 possible risk areas were added and 83 deleted. Further, the attack was reanalyzed assuming all weapons to be surface burst and some 150 counties with a 50 percent or greater probability of experiencing heavy fallout (at least 10,000 roentgen dose) were identified.

It should be noted that there is a certain amount of congruence between these two approaches. Both identified major cities (metropolitan areas or urbanized areas) as risk areas. However, the FCDA listing ignored military targets, such as air bases, whereas the DCPA version gave priority to such targets. Actually, there is no reason why both approaches could not contribute to policy decisions. For example, the boundaries of urban risk areas could be based on census maps of urbanized areas and other military and war-support targets could be added based on attack assumptions. In either case, the results eventually must be "operationalized" for use in civil defense planning and operations. That is, the census tract data on the one hand and the overpressure probability contours on the other must be approximated by reference to physical landmarks, jurisdictional boundaries, or other well-known locational identifiers so that all persons and facilities can be identified unambiguously as subject to the declared policy or not. Current practice is to accomplish the definition of risk area boundaries as part of the population protection planning (PPP) process.

1.7 The Strategic Defense Initiative

Renewed interest in ways to increase the quality and quantity of all-effects shelter in risk areas and to erase existing deficits in fallout protection outside these areas stems from the decision by President Reagan to give priority to research leading to a possible breakthrough in ballistic missile defense. The President announced this decision on March 23, 1983, in the following terms:

> "I am directing a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles. This could pave the way for arms control measures to eliminate the weapons themselves."

The following year, the Department of Defense issued a report[9] of the conclusions of two study groups that had been formed to analyze the technological basis for achieving a highly effective ballistic missile defense and the national security implications of doing so. Pertinent excerpts are:

". . . For the first time in history, we have the possibility of developing a multi-tiered system. Such a system could defend against enemy ballistic missiles in all phases of their flight, not only in the terminal phase where decoys and multiple reentry vehicles (MIRVs) constitute a large number of objects that the defense must cope with. The current technology addresses only the final reentry phase. A capability to intercept missiles in the boost and post-boost phases could defend against a missile attack before the deployment of a multiplicity of reentry vehicles and decoys."

". . . At this time, one cannot prejudge the extent to which costs of increasingly more effective defense deployment will be warranted by the resultant security benefits and defense savings in other areas."

". . . A decision to pursue ballistic missile defenses would have major implications for nuclear strategy, the prevention of nuclear war, deterrence of aggression, and arms reduction. It is with this broad context in mind that our policy on missile defenses must be shaped. To permit informed decisions we have to conduct research on many aspects of the relevant technology and develop a range of specific choices."

"It is likely that components of a multilayered defense, or less than fully effective versions of such a defense, could become deployed earlier than a complete system. Such intermediate versions of a ballistic missile defense system, while unable to provide the protection available from a multitiered system, may nevertheless offer useful capabilities. The development of options to deploy such intermediate capabilities would be an important hedge against an acceleration in the Soviet strategic buildup. If such intermediate systems were actually deployed, they could play a useful role in defeating limited nuclear attacks and in enhancing deterrence against large attacks. . . . Effective defenses strengthen deterrence by increasing an attacker's uncertainty and undermining his confidence in his ability to achieve a predictable, successful outcome."

To carry on the work that these study teams began, Secretary of Defense Caspar Weinberger combined into a single Strategic Defense Initiative Organization (SDIO) previously planned research and development programs in five technology areas. Lt. Gen. James A. Abrahamson, Director of the SDIO, in testimony before a subcommittee of the House Committee on Foreign Affairs on July 26, 1984, emphasized that the Strategic Defense Initiative for now was a research effort leading to a possible future decision to deploy a defensive system. Hon. Franklin Miller, Director, Strategic Forces Policy, Department of Defense, testifying at the same hearing, stated:

"If at some point in the future, the end of this decade, the beginning of the next, the administration decided to come to the Congress to ask you to fund full scale development and beginning deployment, that administration would have to convince you, as well as itself, that such a system would be effective; that it would be cost-effective; and that it would be survivable. Whether a defense system can be developed with these three characteristics is what this entire research program is designed to find out."

The Administration has refrained from attempting to describe the possible nature of a future defense system in advance of the SDI research effort. Most such descriptions and estimates of costs have been made by critics of the idea of a policy change that would emphasize strategic defense. The Arms Control and Disarmament Agency (ACDA), in response to a question from Representative Dante B. Fascell (D-FL) as to whether the Administration's policy was to pursue "a perfect defense (i.e., population defense)" or "a more limited defense of silos", stated:

"The President's Strategic Defense Initiative (SDI) represents a long-term research program to explore the feasibility of an effective defense against a nuclear ballistic missile attack against the U.S. and the Allies. The objective of this research would be to establish the means and cost of destroying ballistic missiles with a multi-tier ballistic missile defense system, thereby reducing the threat of ballistic missiles as an effective weapon system against both populations and military targets.

"The program is designed to allow informed decisions in the early 1990s. Whether a population defense must be perfect to be worth pursuing is a subjective judgment that may need to be made at that time."

In hearings on March 6, 1985, before a subcommittee of the House Committee on Armed Services, Gen. Richard Stillwell of the Department of Defense submitted a letter from Secretary Weinberger that announced a new major review of civil defense objectives in light of the Strategic Defense Initiative. During his testimony, Gen. Stillwell stated:

"I do not see an active defense . . . . ever substituting for passive defense. I mean, no one has indicated any kind of a leak-proof active defense in today's world. Hopefully enough to deter an attack . . . . but certainly only a percentage in terms of effectiveness that needs, in any event, to be supplemented by other measures that could add up, in our view, to 100 percent; therefore, protection of your population."

The inclusion of a nationwide blast shelter system as the "final layer" in a multi-tier ballistic missile defense suggests itself as an alternative to seeking a "perfect" population defense. This shelter system also would serve to protect citizens against other means of nuclear attack, such as aircraft, cruise missiles, and the like. Further, a properly designed national shelter program could improve greatly the protection afforded the people from a range of peacetime hazards against which shelter is a reasonable countermeasure. The investigation of candidate shelter incentive programs reported here has been undertaken in the context of the possible future evolution of the President's Strategic Defense Initiative.

1.8 Statement of Work

The work reported herein was accomplished in response to the Statement of Work for Contract No. EMW-84-C-1570, which is as follows:

> "STATEMENT OF WORK
>
> The Contractor shall furnish the necessary facilities, personnel, and such other services as may be required to design alternative long-term shelter programs for the U.S., to incorporate blast-pressure and fallout protection into new construction by "slanting" design techniques. Alternatives shall include blast pressure shelter incentive payment schemes (similar to the HR 8200 incentive program for fallout shelters, proposed in 1963 and approved by the House but not the Senate), as well as various types of tax incentives. Each option developed should address the costs of the option in detail, deployment strategies, management of the program, and feasibility/acceptability issues. Design of alternatives will consider shelter program experience both here and abroad, as well as the multi-hazard utility of sheltering programs. Stress will be placed on the feasibility and acceptability of alternative programs, and work will include a draft of legislation required. This study should address program issues including the details of deploying and managing alternative programs (e.g., direct payment of incremental costs for shelter, or tax incentives of various types), the potential costs to the Federal Government, as well as the acceptability of such programs to building owners and architects and engineers.
>
> "The end product shall be a recommended optimum program design based on an analysis of alternatives, and U.S. and foreign experience, as well as cost, deployment and management issues, and evaluation of feasibility and acceptability by builders and by Congress."

The remainder of this section is devoted to a description of U.S. and foreign experience with programs for the incorporation of shelter in new construction and the general characteristics of such programs. Section II projects the amount and kind of new construction that may be available for slanting to provide new blast or fallout shelter. Slanting criteria and costs are covered in Sect: n III. In Section IV, various incentive options designed to induce shelter in new construction are described and evaluated. Program management alternatives are explored in Section V. The information in these sections is employed in Section VI in the design of eleven alternative shelter programs that are evaluated in Section VII. Our conclusions and recommendations will be found in the concluding section.

1.9 The FCDA Shelter Proposal

The first major proposal for a nationwide shelter system was made to President Eisenhower by the Federal Civil Defense Administration (FCDA) in 1956. FCDA proposed to build 30-psi blast shelters in urbanized areas and fallout shelter elsewhere at an estimated cost of $32 billion over an eight-year period, with completion in 1965. The proposal caused the President to call for a study of continental defense issues (the Gaither Study). The Gaither Panel recommended a fallout shelter system at a cost of $20 billion but the Eis nhower Administration took no steps to implement the recommendation.

As part of the Gaither Study, one of this report's coauthors prepared a shelter program analysis[10] that offers some insights of use in the present analysis. In the design of alternative programs, an effort was made to give priority to "multi-purpose" shelter ("slanting" of new construction) over single-purpose construction, then to designs that were efficient with respect to structure cost, and to locations requiring no expenditure for land. For example, attention was focused on schools because they are colocated with the residential population and land was assumed to be available. It was estimated that 20 percent of the population either attended or worked at elementary and secondary schools. It was estimated that twice that number could be sheltered at urban schools and about 1½ times that many at rural school locations; that is, 40 percent of the urban population (central cities and urban fringe) could be sheltered at schools and 29 percent of the rural population.

It was estimated that the population increase to 1965 would be about 15 percent. Hence, about 15 percent of schools would be built during the period and most could be slanted to provide the desired shelter protection. Conservatively, two-thirds of new schools were assumed to incorporate shelter.

This meant that 4 percent of the urban population would be sheltered in blast-slanted schools and 36 percent in single-purpose shelters constructed on school grounds. Similar considerations for other categories of buildings led to program mixes in which 10 percent or less of shelter spaces were in multi-purpose buildings. Moreover, no attempt was made to estimate the incremental cost of incorporating shelter protection in new construction. The entire cost of the shelter space was taken to be the shelter cost even though the space had a peacetime use and economic worth. Indeed, it was assumed that not all of the protected space would be available for shelter use because of the peacetime use. Hence, dual-use space cost more than single-purpose shelter. There was no economic incentive to exploit the possibilities of the slanting of new construction to provide shelter.

Neither the Gaither Study nor the FCDA shelter proposal dealt with shelter incentives. It was assumed, apparently, that the program, if adopted by the Government, would be obligatory, with the Government paying all costs. The cost of shelters varied with size, with the smaller shelters appropriate to suburban and rural areas costing more than large shelters. The size mix was based on estimates of the numbers of people who could reach shelter with a 15-minute warning. Structure costs for single-purpose fallout shelter ranged from $3 to $6 per square foot; 30-psi shelter ranged from $10 to $25 per square foot; 100-psi shelter, $16 to $38 per square foot, all in 1957 dollars. The Gaither Panel recommended a nationwide fallout shelter program but the recommendation was not approved by the President.

1.10 Prototype Shelter Program

During the fiscal years 1960 and 1961, Congress appropriated $5 million ($2.5 million each year) for the Federal portion of an experimental fallout shelter program designed "to provide public demonstration models and to stimulate shelter construction."[11] The program originally contemplated 935 shelters, of which 256 would be family size, 79 would be larger group shelters, and 600 would be located at high schools. The 600 high school shelters were to be constructed by their vocational departments using a Federal incentive payment of $250. By the end of 1962, 658 prototype shelters had been approved, of which 611 had been completed. The Office of Civil Defense (OCD) asserted[11] that the program had contributed valuable information on shelter construction and would add about 50,000 spaces to the nationwide shelter inventory.

1.11 Shelters in Federal Buildings

Including fallout shelter in existing and new Federal buildings was early recognized as important more to demonstrate Federal leadership than to augment the amount of shelter inherent in building basements and other areas. The General Services Administration requested $2 million each year from 1961 to 1963 to modify existing Federal buildings for this purpose but the requests were denied by the Congress. In September, 1959, the Office of Civil and Defense Mobilization (OCDM) issued a directive to the heads of all nonmilitary departments and agencies that fallout shelters would be incorporated in new Federal buildings.[12] Funds for inclusion of fallout shelter were to be included in budget estimates beginning fiscal year 1962. However, the appropriations bills specifically disallowed these funds.

In 1961, prior to the Berlin Crisis, President Kennedy transferred responsibility for civil defense to the Department of Defense and requested a large ($207 million) supplemental appropriation from the Congress. Passed without a dissenting vote by both Houses, the appropriation contained $17.5 million for the inclusion of fallout shelter in existing and new Federal buildings. These were the first significant funds available for the incorporation of shelter into new and existing Federal buildings. According to Reference 11, 701 projects were planned during 1962 that would add more than 500,000 spaces to the national fallout shelter inventory at an average cost of less than $32 per shelter space. Most of the funds were allotted to construction projects under the General Services Administration. Shelter was designed into about 125 projects before a new requirement for specific authorization was established by the House Appropriations Committee in 1963. The determination as to which Federal buildings would be built or be modified to incorporate public fallout shelter was provided by the Office of Civil Defense. Because of the requirement for specific authorization, only a small part of the appropriated funds had been obligated by 1963.

1.12 The Fallout Shelter Incentive Proposal (HR 8200)

In 1963, the Office of Civil Defense, with the approval of President Kennedy, proposed an amendment to the Federal Civil Defense Act that would make the inclusion of fallout shelter mandatory in new Federal buildings and would authorize a financial incentive to provide fallout shelter in the construction or modification of buildings owned by State and local governments and nonprofit entities. The bill originally was designated H.R. 3516, 88th Congress, 1st Session. After extensive hearings, it passed the House as H.R. 8200 but was deferred in the Senate.

The circumstances under which H.R. 8200 was considered included the decision by President Kennedy to implement the fallout shelter program recommended by the Gaither Panel, damage assessment studies that demonstrated that the quality of fallout protection inherent in many large buildings would save many millions of lives, and the occurrence of the Berlin Crisis and the Cuban Missile crisis. The transfer of civil defense functions to the Department of Defense in 1961 had seen the launching of the national fallout shelter survey. At the time of the hearings on H.R. 8200, 100 million shelter spaces had been identified. (A shelter space is equal to 10 square feet of usable floor area.) One-third of these spaces had a fallout protection factor (PF) between 40 (the minimum considered acceptable) and 100; one-third had a PF between 100 and 250; one-third from 250 to greater than 1000. Protection factors measure the degree of interruption of gamma radiation. Radiation exposure at a given location would be 100 times greater if a person were completely unprotected instead of being in a shelter having a protection factor of 100.

The fallout shelter incentive program was presented to Congress as the next step: to extend the results of the shelter survey through minor improvements that would create new shelter space and incentives to influence building construction by making minor changes in design to increase the quantity and quality of fallout shelter. As an example of the former, it was stated that improved ventilation in basements could increase the capacity of these shelter areas by three or four times. The second approach, of course, involved slanting the designs of new buildings to increase the amount of protected space by eliminating some ground floor windows or providing baffles for openings, thickening masonry walls, and adding overhead mass.

The proposed legislation consisted of two parts. The first, a new Section 206 in the Federal Civil Defense Act, established a mandatory requirement that public shelter "be incorporated in all structures existing or to be constructed in the future and owned or occupied by any department or agency of the United States whether civilian or military, unless exempted from such shelter requirement . . ." The grounds for exemption in the initial bill were to be set by the President and were generally referred to as factors that would make unnecessary, uneconomical, or impractical the incorporation of public shelter. In the final bill, the House Armed Services Committee, which was responsible for the legislation, made the grounds for exemption much more specific. Although represented as "tightening up" the provision in the Administration's bill, it would appear that the changes actually would have had the effect of relieving the Department of Defense of the shelter requirement in most of its construction. The changed language read:

> "Regulations establishing exemptions shall be limited to the following bases for exemptions:
>
> (1) The proposed shelter would be in areas where additional public shelter space is not required;
>
> (2) The only practical design or construction characteristics of the structure with shelter incorporated therein would result in exceeding cost limitations, which shall be set forth in said regulations to maintain an average of not to exceed $4 per square foot, for shelter developed in any one fiscal year:
>
> (3) In the case of a leased structure, the term of the lease, together with terms of options to renew, is less than an aggregate of ten years;
>
> (4) Competitive bidding for property to be leased by the Federal government would be unduly impaired by requirements for the inclusion of shelter features in the building to be leased;
>
> (5) The operational use of the structure is such that the proposed incorporation of shelter would impede or impair its operational mission;
>
> (6) The proposed shelter would be in restricted areas not available to the public in time of emergency; or
>
> (7) It would be unnecessary, uneconomical, or impractical to include shelter in a particular shelter."

Item (2) of the basis for exemption established a cost limitation of $4 per square foot for new fallout shelter. Such limitations, although considered necessary to form an objective basis for granting an exemption for "uneconomical" projects, have several undesirable consequences:

(a) The design process becomes more costly because the parts of the structure involved in sheltering must be designed and costed with and without shelter to establish the incremental costs.

(b) The owner/designer may be motivated to incorporate ineffective or overly expensive design changes in order to qualify for an exemption. There is little incentive to learn innovative cost solutions to design problems.

(c) A cost limitation can be an invitation to some to attribute other building costs to the incremental cost of shelter; e.g., the cost of basement excavation even though a basement would have been provided without shelter considerations.

On the other hand, the Administration argued that the mandatory incorporation of shelter in Federal buildings would accomplish the following:

(a) Demonstrate leadership in the shelter program by the Federal Government.

(b) Help meet local deficiencies in public shelter space (estimated yield of about 5 million spaces).

(c) Provide a method to acquire cost data on the construction of public shelters.

(d) Develop methods of lowering the cost of incorporating shelter in many institutional types of buildings.

(e) Afford the opportunity to develop designs useful elsewhere and to develop working experience in protective construction design among the thousands of architects and engineers engaged annually on Federal projects.

The second part of the bill concerned the incentive program and took the form of a proposed Section 207 of the Federal Civil Defense Act. It was proposed to provide a financial payment for the inclusion of fallout shelter in the buildings of schools, hospitals, State and local governments, and other nonprofit institutions. The logic for confining the scope of the program to these entities lay partly in the desire to initiate the program on a relatively small scale with respect to the total shelter requirement and partly because it was unlikely that funds would be diverted from other public purposes at the local level into shelter building.

The incentive payment was set at $2.50 per square foot ($25 per shelter space) or the actual cost of providing additional shelter, whichever was less. The typical cost of fallout shelter in new construction was alleged to be $4 per square foot ($40 per shelter space). However, the shelter survey had found very good fallout shelter in many large buildings without any intentional design slanting. The requirement that the incentive payment be a ceiling amount or actual cost, whichever was less, would, as noted earlier on, force a cost comparison between two designs, one with slanting and one without. Whether it also was the intention to evaluate the two designs for fallout shielding and pay only for the net increase in shelter space was not made clear nor did anyone raise this question during the H.R. 8200 hearings. In any event, OCD bypassed the issue by making the point that the funds authorized for the trial year would only be sufficient to cover low-cost opportunities to increase the amount of shelter in existing buildings, such as improving the ventilation of basements. The average cost per shelter space under these circumstances was projected to be $16.35 per shelter space.[13] As reported out by the Armed Services Committee and passed by the House of Representatives, the bill included the condition that "payment shall not exceed $2.50 multiplied by the total square feet of public shelter space provided in respect to an approved application." (Emphasis added.)

1.13 The Experimental Incentive Proposals

Since H.R. 8200 never became law, it cannot be determined whether the incentive payment plan would have induced a high level of participation by the targetted groups: State and local governments and nonprofit institutions. Doubts were expressed in the hearings[13] because OCD alleged that the average cost of fallout shelter would be $40 per shelter space (10 square feet) whereas the incentive payment was only $25 per space. Would these groups put up the difference to get fallout shelter? And, if not, what proportion of the projects would fall far enough below the average to be fully subsidized? Further, how much could the average cost be lowered as architects became experienced in "slanting" the design of new buildings?

OCD had begun a program of technical training in 1961 to qualify architects and engineers to help identify existing fallout shelter. By the summer of 1962, about 2,600 qualified graduates were available nationwide. Moreover, OCD established a professional advisory service at headquarters and the regions. This service was rendered principally by direct consultation and by the distribution of technical publications. By the end of fiscal year 1962, several hundred architectural and engineering firms engaged in designing schools and other buildings had consulted the OCD staff.

The results were impressive. In January, 1965, OCD published[14] architectural sketchs and photographs of 19 schools and 15 other buildings that had been built with fallout shelter and without any incentive other than the availability of technical assistance. A summary of school costs also was provided in the publication. Key data are shown in Table 1.1.

The sixteen schools for which cost data are available (item 9 in Table 1-1 covers three schools) provided over 26,000 shelter spaces, about 75 percent more than the school population of about 15,000. This may be compared with the 100 percent assumption used by the FCDA and the Gaither Panel a decade earlier. In no case was shelter provided for less than the school population. Noteworthy was the fact that the cost per shelter space did not exceed $25 in any school. Some costs approached half this value. If H.R. 8200 had become law, all of these schools would have been fully subsidized by the Federal Government. As it was, school boards in these instances were willing to increase building costs by up to 7.5 percent based only on the provision of technical assistance.

In 1966, OCD proposed to initiate an "experiment" to increase the amount of fallout shelter in new buildings by offering a Federal grant to building owners. Up to one percent of the total project cost for the added shelter cost was proposed for "slanting" the building design and agreeing to its use as a public fallout shelter. Congress declined to approve the ten million dollars requested for a one-year experiment. This OCD proposal was the first that defined the incentive ceiling in terms of a percentage of the project cost. Unless other criteria must be met, this kind of ceiling can be met by reducing the amount of shelter space produced. The data in Table 1.1 suggest that if only the school population were provided shelter about 10 percent of the building area would be needed and the shelter cost would approach one percent of the project cost. Certainly, many schools and other buildings could be fully subsidized under the one-percent formula.

Shelter costs as a percentage of project costs also can be increased by increasing the percent of the building qualifying as shelter, as can be

TABLE 1.1

1964 SCHOOL SHELTER COSTS*

	SCHOOL PROJECT	PERCENT OF BUILDING PROVIDING F.O. SHELTER	COST PER SPACE	SHELTER COST AS PERCENT OF PROJECT COST
1.	Cascade Junior High, Longview, WA	19.9	$13.30	2.3
2.	Bemus Point High, Chautauqua, NY	9.5	22.70	1.3
3.	Lincoln Elementary, Alva, OK	15.5	20.00	2.6
4.	United High, Laredo, TX	42.6	18.20	7.5
5.	Coral Park High, Miami, FL	14.7	21.10	2.4
6.	Carol City High, Miami, FL	15.7	12.90	1.7
7.	West Dunbar Elementary, Miami, FL	20.1	25.00	4.6
8.	William Floyd High, Shirley, NY	12.3	18.20	1.1
9.	Three Schools in Orlando, FL	37.4	15.70	3.5
10.	Mayville High, Mayville, WI	6.8	23.70	1.2
11.	Park Junior High, Artesia, NM	35.7	17.40	5.3
12.	Glades Junior High, Miami, FL	15.2	12.50	1.6
13.	Goddard High, Roswell, NM	44.2	15.80	6.7
14.	North Central School, Rogers, ND	15.1	13.80	1.9

*Based on data in Reference 14, pp. 58-59 seen in Table 1.1. Other devices for exceeding a cost ratio include designing in a higher degree of protection than the minimum required, providing more generous added ventilation, housekeeping, and other equipment, and allocating borderline construction costs, such as excavation, to the shelter. In the 1966 Military Construction Act, fallout shelter was required for all new construction projects at military installations, provided that the estimated cost of shelter did not exceed one percent of the project cost. This mandatory requirement remained in effect for some 15 years until removed at the request of the Department of Defense. During this period, a considerable amount of military construction, notably in the Air Force, was designed to include fallout shelter. However, the one-percent ceiling on shelter costs permitted most buildings to be built without shelter at the desire of the military department.

In 1970, OCD again proposed an experimental shelter program to the Congress. The purpose of the program was to (1) determine the effectiveness of a Federal grant in producing additional shelter in deficit areas, (2) determine owner/architect acceptance of regulations governing grant payments, and (3) test alternative administrative procedures. Although Congress did not approve the program, its characteristics are particularly important to the purposes of this study.

As background, by 1969 nearly 20,000 architects and engineers had been trained as fallout shelter analysts and Advisory Service Centers were functioning at 45 universities to provide technical assistance to architectural firms. The Direct Mail Shelter Development System (DMSDS) was introduced in 1968 to contact architect/owners of new projects by mail, urging the incorporation of fallout shelter in the design and offering technical assistance at no cost. During 1969, over 10,000 solicitations were made. The University Advisory Centers actually made recommendations on about 10 percent of these: 1,044 buildings. If adopted, the buildings would have contained about 800,000 fallout shelter spaces at an average cost of about $7 per space.[15] This added cost is about half the lower costs in Table 1.1 and less than 30 percent of the ceiling proposed in H.R. 8200. Even so, only about one quarter of these buildings actually were built to include shelter. The majority of the building owners declined to bear the small additional cost of shelter. A small-scale experimental grant program was proposed to form a basis for a later full-scale grant program.

The experiment was to start with a flat-rate payment of $10 per shelter space, a rate that might be changed in the course of the experimental program. This was a significant innovation, as a flat-rate payment irrespective of actual shelter costs avoids the need for added design effort to determine the incremental shelter costs and motivates the architect to examine ways to reduce costs and thus "make a buck" for his client, the building owner. A central purpose of the proposed experiment was to explore the incentive characteristics of the flat-rate payment.

Another important innovation was the exclusion from the program of projects costing less than $200,000. Some of the reasons for placing a floor on project cost are: (1) small buildings often are of light construction and not suitable for shelter purposes except at excessive cost; (2) OCD had determined that it was impractical to provide trained leadership and shelter supplies for shelters holding less than about 50 persons; and (3) a floor on project cost eases administration of the program by eliminating a large number of projects that contribute very little to the provision of shelter.

The experimental program also excluded buildings costing over $5 million or with more than five stories. These exclusions illustrate how a program can be designed to deal with specific technical issues. In the case of fallout shelter, the national shelter survey had indicated that high-rise buildings would have abundant amounts of shelter space on the middle floors. Additional shelter would be unnecessary. A similar conclusion applied to very large buildings of any kind. Moreover, a very large construction project would absorb too much of the relatively limited funds requested for the experiment. It might be noted that all of the schools shown in Table 1.1 had project costs between $200,000 and $5 million. Another reason for excluding high-rise buildings was that the program was aimed at the suburban and rural areas where there was a shortage of fallout shelter and high-rise buildings were rare.

The basic administrative procedure was to use the DMSDS to invite a random sample of owners of proposed new buildings to participate. Interested owners would be asked to supply basic information about the proposed building which would be used to make an estimate of the inherent shelter space likely if no slanting occurred. A deal would be struck to pay the flat rate for all shelter spaces over the mutually agreed inherent number.

1.14 State Shelter Legislation

In the mid-1960s, three States enacted legislation making it mandatory to include fallout protection for at least the building occupants in all buildings constructed with State funds. These were Alabama, Arizona, and Rhode Island. These laws were generally based on or similar to the mandatory section of H.R. 8200 that would have applied to Federal buildings. Each State law included a provision for granting a waiver to the shelter requirement for reasons that would make unnecessary or impractical the incorporation of shelter. A key basis for exemption was an economic factor linked to a percentage of total project cost. In Alabama, a sliding scale was adopted: 4 percent of project cost for projects costing between $50,000 and $500,000; 3 percent for projects costing between $500,000 and $1.5 million; 2 percent for projects costing over $1.5 million. In Arizona, a waiver could be granted if the additional cost was more than 3 percent of the total building cost, exclusive of land, architectural fees, equipment, and off-site improvement. The Rhode Island law used 3.5 percent of total project costs.

The foregoing bases for exemption on economic grounds were relatively generous considering the rapid reduction in incremental costs of shelter described above and initially State-funded projects incorporated fallout shelter although many school officials were unhappy that some construction funds were in their eyes being devoted to non-educational purposes. However, as Federal leadership eroded through Congressional inaction and the University Advisory Centers were phased out because of cuts in the civil defense budget, architects of State-funded projects were quick to take advantage. The three States were inundated with waiver requests and did not have the technical resources available to review the requests adequately. The Alabama and Arizona laws remain on the books today but few if any State-funded projects contain other than inherent fallout shelter.

New York State, under the leadership of Governor Nelson Rockefeller, was the only State that ever offered a financial incentive to incorporate fallout protection in new building designs. Under the State program initiated in 1962, school authorities were encouraged to include fallout protection in new school designs or modifications. The State would pay one-half the cost of shelter construction or $25 per shelter space (whichever was the lesser amount). The fact that the program was available only for school construction was rather limiting in scope. In the first five years of operation, forty school buildings were designed with deliberate fallout protection (50,937 shelter spaces having a protection factor of PF 100 or more) at a cost to the State of $1,235,000. After several years of further operation with relatively few "takers", the New York State Legislature rescinded the incentive program when other demands for State funding resources took priority.

In 1961, prior to the enactment of the broader, mandatory law discussed above, Rhode Island enacted legislation that amended its laws on property subject to state taxes. The act provided that improvements amounting to $1,500 to property to provide fallout protection would be exempt from taxation. The limitation was appropriate to family-type shelters. It is not known whether this legislation was effective in stimulating the construction of home fallout shelter in the State.

In the course of this study, Alabama officials responsible for enforcing the current shelter were interviewed. State projects now routinely request and are granted waivers from the shelter requirement. The situation is blamed on the failure of Federal leadership and support. On the one hand, failure of the Congress to enact H.R. 8200 into law or at least to mandate the inclusion of fallout shelter into Federal buildings sent the wrong signal to the States, precipitating a flood of waiver requests. On the other hand, the loss of technical assistance when the University Advisory Center at Auburn University was shut down left the State Building Commission and the State Emergency Management Agency in no position to resist the architectural practice of overdesigning the shelter area to exceed the 3 percent ceiling. It appears that both Federal example and Federal technical asisstance would have been necessary for success.

With respect to multi-hazard shelter programs, Mr. Lawrence Bowden, Deputy Director of the Alabama Emergency Management Agency, stated:

> "It is my opinion that such legislation [on the construction of blast shelters] is necessary if this country is indeed serious about preparing for a nuclear attack on this country. We have been toying with, skirting, and giving lip service to this issue long enough.
>
> "The legislation should be mandatory so that it will be effective and also so that it would make the increased cost of construction applicable across the board and would eliminate inequities in these costs.

"It also seems feasible to tie the compliance inspections, etc., to the existing FEMA Facility Survey Program. I believe this Program is now in effect in all the states and it could be expanded to accommodate this concept."

The Alabama officials contacted saw no problems at the State level in responding to and participating in a mandatory Federal shelter law.

1.15 Foreign Shelter Experience

A significant number of West European nations have active shelter programs. Some of these are of long standing. Because of cultural, political, and strategic differences between these nations and the United States, one must be cautious about interpreting this foreign experience for application to a U.S. program. European programs differ significantly from nation to nation. However, there are some common characteristics. Nearly all are "blast slanting" programs; that is, they involve the incorporation of shelter in new buildings rather than the construction of single-purpose shelters. For this reason, the detailed program characteristics are of interest. Another common characteristic is that European shelter programs are mandatory programs. Shelter must be included in most new buildings. The mandatory nature of these programs does not preclude the provision of incentives or cost-sharing arrangements. Some of the program details of foreign shelter programs are outlined in subsequent paragraphs.

1.16 The Swiss Shelter Program[16]

Civil defense in Switzerland is one of the most highly developed in the free world. Over 80 percent of the costs of Swiss civil defense are represented by shelter construction. The shelter program began in 1950 with a Federal decree requiring the construction of shelters in new buildings in communities larger than 1,000 inhabitants. This decree was expanded in 1963 to require localities to build public shelters where private ones could not be built. The 1963 law gave Switzerland an ambitious but "economically bearable" shelter construction program. At the time of its enactment, the Swiss were about to experience an unprecedented construction boom that resulted in a large increase in the shelter inventory. By 1980, fully 75 percent of the Swiss population had shelter. The remainder still used makeshift or best available refuges.

Swiss population shelters are typically built into the basement of a new building. It is simply a reinforced concrete box designed to resist at least one atmosphere of overpressure (15 psi). The law states that the increase in building cost due to the shelter shall not exceed 5 percent of the building cost, land excluded. This cost, 5 percent or less of project cost, is shared: one-half by the building owner and one-half by the federal government. For public shelters, the local government pays 70 percent; the federal government, 30 percent.

1.17 <u>The Finnish Shelter Program</u>[17]

Finland enacted a civil defense law in 1958 that mandated the construction of blast shelters in risk areas, so-called Civil Defense Target Areas. At present, a shelter must be constructed as part of or in the immediate vicinity of each new building having a volume of 3,000 cubic meters or more. (This would exempt buildings with a floor area less than about 10,000 square feet or costing about $500,000.) In residential or similar buildings, the shelter space must amount to 2 percent of total floor area, allowing 6.5 square feet for each building occupant. Shelters in industrial and commercial buildings must accommodate the employees. The building owner is not compensated for the added cost, which is said to vary between two and five percent of project cost for basement shelters in apartment houses.

Most of the Finnish blast shelters are in the basements of apartment buildings and are designed to resist an overpressure of 15 psi. There are two other classes of blast shelter designed to resist higher overpressures that are generally cut out of the solid rock prevalent in Finland and Sweden. No shelters are required outside the risk areas but a proposal is under consideration to require equipped fallout shelters there. Municipalities within risk areas are responsible for constructing public shelters for those not having access to private shelters but this construction has tended to lag. At present, about 75 percent of the population in risk areas have access to blast shelter.

1.18 <u>Scandinavian Shelter Programs</u>

Denmark, Norway, and Sweden all have long-standing shelter programs based largely on laws requiring the inclusion of all-effects shelter in new construction in designated risk areas. In Denmark, the program has resulted in roughly 3.4 million shelter spaces for a population of about 5.1 million. In Norway, all new private buildings of more than about 1,600 square feet and all new public buildings must contain blast shelter. About 70 percent of the urban population now have such protection. The shelter goal in Sweden is to provide every citizen with blast shelter protection at or near both place of work and residence. Shelter must be incorporated into all new construction where necessary, feasible, and usable for peacetime purposes. Public shelter is financed by the State. About $12 per capita is allocated to civil defense annually and about 200,000 blast shelter spaces added to the inventory of about 6 million (70 percent coverage).

1.19 Other Foreign Shelter Programs

In the Netherlands, shelter is available for approximately half of the population, mainly in the larger cities. Much of this shelter is incorporated in subway systems. The Government subsidizes part of the cost of incorporating shelter in new multi-story buildings but not in single-family homes. All new one-family structures in the Federal Republic of Germany must include shelter. The Government provides a subsidy in the form of tax relief. Somewhat over 2 million shelter spaces have been created. Recently, the Turkish government made the incorporation of shelter in new construction mandatory in the larger cities but no data on progress is available. The Belgian government has the authority to mandate shelter in new buildings but few shelters have been built.

It should be noted that although some Western European shelter programs are of long standing, there is little of this experience that is directly transferable to the U.S. situation. Social, political, and economic factors differ significantly. Construction practices and costs also are difficult to interpret. Recently, a large sports facility was created in solid rock near Oslo, Norway, at a cost of about $82 per square foot, a cost similar to the cost of aboveground schools and office buildings in the United States. Except for such facilities, most European shelters are designed to resist one atmosphere (15 psi) of blast overpressure. The shelter space allotment usually is about half the U.S. standard of 10 square feet per person. However, if a multi-hazard shelter incentive shelter program were to be undertaken in this country, European developments in such items as blast closures may be quite valuable.

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SECTION II

PROJECTIONS OF SLANTABLE CONSTRUCTION

2.1 The Universe of New Construction

The basic concept underlying the shelter incentive programs evaluated in this study is that the design of new structures can be modified so as to increase the quantity and level of protection provided against natural, technological, and attack related hazards without adversely affecting the appearance, function, or utility of the structures for their primary purpose. This deliberate modification of structural design is called "slanting." If the primary criterion for assessing the value of a candidate shelter program of this kind is the number of people provided shelter over a period of years, then it is necessary to project the amount of new construction in the future that is susceptible to slanting techniques and to estimate the amount of shelter that could be incorporated into the various kinds of structures that will be built. Such estimates would represent the potential yield of shelter space if all slanting opportunities were realized.

The primary source of data available for use in projections of new construction are the reports prepared by F. W. Dodge Division of the McGraw-Hill Information Systems Company. Through an extensive reporting system throughout the country, the F. W. Dodge Division identifies new construction projects of all kinds and follows each in considerable detail from earliest concept through design and construction, as discussed in Section V. This organization also publishes a variety of summaries and analyses for the construction industry, of which the most useful for this study is the annual construction outlook.[1, 2] This document is issued in October each year by the Economics Department of McGraw-Hill. It summarizes new construction for current and past years and projects the amount of construction for the following year. Longer range projections are undertaken only for specific purposes beyond the scope of this study. However, the historical data contained in the annual construction outlook documents are a sufficient basis for the present purpose.

2.2 Non-Residential Construction

Figure 2.1 summarizes the amount of new building construction since 1973 in terms of billions of square feet of new building floor space produced.

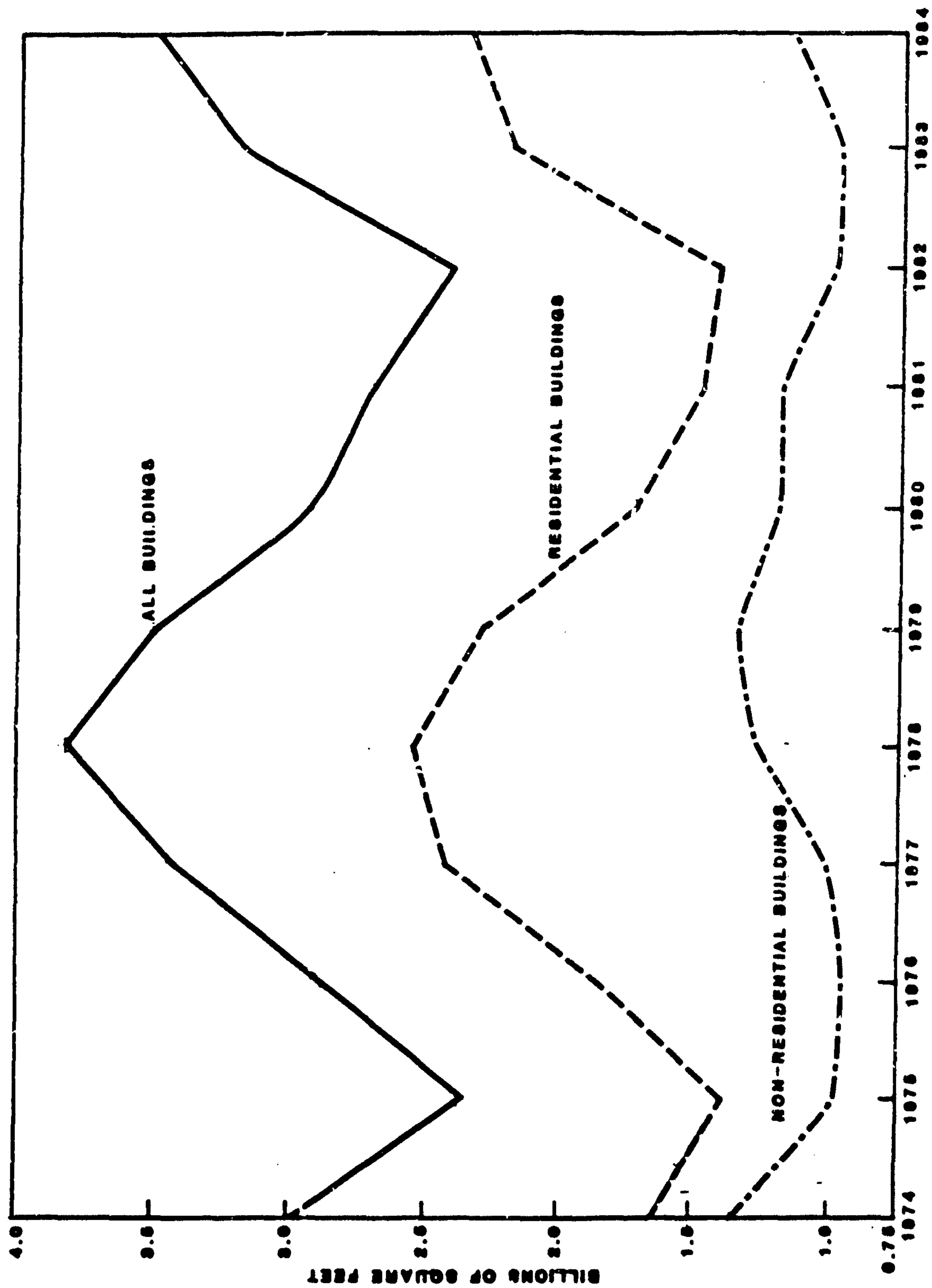

Figure 2.1 New Building Construction In Past Decade

The lower set of data is for non-residential buildings and is taken directly from charts and tables in References 1 and 2. It can be seen that the amount of new construction in this category has varied from year to year but not greatly. On the average, about 1.14 billion square feet of space have been added each year over the past decade, with individual years varying as much as 20 percent around this average. The variations are usually ascribed to general economic conditions, the lows reflecting recessions and the highs reflecting periods of economic growth. The actual reasons for variation are undoubtedly more complex. For example, demographic changes play a role. New school construction has seen a downward trend as the "baby boom" has grown up and hospital and nursing home construction has increased as the population has aged. Currently, the office building market is overbuilt in many areas. These considerations do not alter the fact that there has been no detectable trend either up or down in the total amount of new non-residential construction in the past decade and this is not likely to change. Thus, it can be assumed that somewhat over a billion square feet of this kind of construction will be built each year on the average over the remainder of this century.

2.3 Residential Construction

The intermediate set of data in Figure 2.1 charts the construction over the past decade of new residential buildings or, more precisely, "housekeeping residential" buildings. The data is based on information in References 1 and 2 that is in terms of "dwelling units" or "housing starts." Tables for years 1983, 1984, and 1985 show both numbers of dwelling units and floor area for single-family houses and multifamily housing. For single-family units, the average floor area per unit is about 1,550 square feet, whereas the floor area for multifamily units is about 950 square feet. About two-thirds of the dwelling units are single-family units. The weighted average for all dwelling units is about 1,300 square feet per unit and this factor has been used in Figure 2.1 to convert annual numbers of dwelling units to floor space.

It can be seen that floor space in new residential buildings also varies from year to year, depending on economic and other factors. On the average, about 1.94 billion square feet of space have been added each year, with some years varying as much as 30 percent around this average. Again, there is no detectable trend in the data over the past decade. Thus, it can be assumed that about two billion square feet of this kind of construction will be built each year on the average in the next decade. Two-thirds of this space will be found in single-family houses.

The upper trend line in Figure 2.1 is simply the sum of the two curves below: residential and non-residential buildings. On the average, about 3.1 billion square feet of floor area has been added each year, with variations of as much as 25 percent about the average. About half of this space has been produced in single-family houses.

Although the upper trend line is labeled "All Buildings," this is not quite correct. One category of residential construction, "Nonhousekeeping Residential", is not included in the historical data of References 1 and 2. Nonhousekeeping residential construction includes hotels, motels, and similar buildings. In 1983, there was 75 million square feet of floor area in this category; in 1984,. 100 million square feet. This represents a small addition to the total building construction.

2.4 Average Construction Year

As noted above, it appears sufficient for projecting new construction to ignore the year-to-year variation in construction volume and to assume that the average rate of construction during the past decade will persist over the next 10 to 15 years. However, it will be necessary for the design of shelter incentive programs to analyze the characteristics of an average construction year in much greater detail than is shown in Figure 2.1. One convenient approach is to select one particular year as representative of the average construction year. Since projections are to be made into the future, it is desirable that the selected year be among the most recent so that current trends in building design and construction are reflected to the greatest extent possible. The year 1983 is a good choice for this purpose. It is the most recent year for which relatively complete data is available. As can be seen in Figure 2.1, the total floor area of about 3.2 billion square feet is close to the average. The amount of residential space is somewhat above the average and the amount of non-residential space is somewhat below the average but the adjustments needed to reflect the average construction year are minor. Table 2.1 shows key construction data for 1983 drawn from Reference 1.

TABLE 2.1

1983 NATIONAL CONSTRUCTION DATA*

CATEGORY	FLOOR AREA (Million Sq. Ft.)	VALUATION (Million $)	COST PER SQ. FT.
Office Buildings	252	$18,300	$72.62
Commercial	360	13,600	37.78
Manufacturing	101	5,425	53.71
Educational	71	6,075	85.56
Hospital and Health	80	8,600	107.50
Other Nonresidential	119	8,775	73.74
TOTAL NONRESIDENTIAL	983	$60,775	$61.83
One-Family Houses	1,580	$62,450	$39.53
Multi-Family Housing	628	23,975	38.18
Nonhousekeeping Residential	75	5,300	70.67
TOTAL RESIDENTIAL	2,283	$91,725	$40.18
ALL BUILDINGS	3,266	$152,500	$46.69
Highways & Bridges		$15,450	
Sewer & Water		7,525	
Other Public Works		6,750	
Utilities		9,500	
TOTAL NONBUILDING CONSTRUCTION		$39,225	
ALL CONSTRUCTION		$191,725	

*Floor area and valuation taken from Reference 1.

In terms of both floor area and valuation, one-family houses dominate the construction picture shown in Table 2.1, providing more floor area and dollar value than all nonresidential buildings combined. Clearly, imaginative ways to incorporate shelter in this major construction category must be found if the full potential of shelter incentive schemes is to be realized. Multi-family housing also is a major construction category. This category includes apartment houses, which are relatively large structures, but it also includes 2- and 3-family dwellings, which are more like one-family houses. Nonhousekeeping residential structures (hotels, motels, dormitories, and barracks) constitute a relatively minor construction effort compared to residential housing.

Among the nonresidential categories of construction, the commercial category (stores, banks, services) contains the largest amount of floor space, about 360 million square feet. Office buildings, with about 250 million square feet, are also a major nonresidential construction category with the highest valuation. Together, manufacturing, educational, and health facilities are about equivalent to offices in their contribution to the construction potential. The category, "Other Nonresidential", includes, among others not fitting into the other categories, those buildings associated with "Nonbuilding Construction", such as sewer and water treatment plants, electric power plants, dams, and other public works projects.

2.5 Project Size and Location

The F. W. Dodge data summarized above is useful in defining the general nature of the construction universe and the trend of construction over the past decade. It does not provide, however, sufficient detail to form a basis for the design of candidate shelter incentive programs. It does not give any indication of project size nor does it provide any locational data, such as the proportion of construction in cities as opposed to rural areas. This information could be obtained by analysis of the individual project records on which the F. W. Dodge construction outlook reports are based but such detailed analysis was beyond the scope of this study. Rather, we obtained from the Bureau of the Census their data on the issuance of building permits during the calendar year 1983, our "average" construction year. These data have been summarized by Census-defined geographic areas. They also provide information on the number of projects for which building permits were issued and, hence, the average cost of a project. The essential data is shown in Table 2.2.

As can be seen, the Census breakdown of use classes is more detailed than that shown in Table 2.1 This causes some problems in reconciling the two sets of data. Moreover, some limitations of the Census data are: (1) the permit-issuing jurisdictions that report account for 90-92 percent of building construction, (2) the Census data do not account for new construction owned by Federal, State, and local governments, school boards, and other governmental authorities that are not required to obtain building permits, and (3) there is some evidence that construction costs on building permits may be understated. Thus, the Census figures can be expected to be lower than the F. W. Dodge figures. This can be confirmed by comparison of the "bottom lines." The total valuation for all buildings in Table 2.2 is $131,159 million, which is 86 percent of the amount in Table 2.1.

2.6 Reconciliation of the Data

The difference between the Dodge and Census data would be much greater were it not for the inclusion in Table 2.2 of two entries labeled, "Additions and Alterations," one for nonresidential construction and one for residential buildings. This category of construction is maintained separately by the permit data reporting process but is incorporated into the appropriate categories of the Dodge data. Table 2.2 shows that the average addition or alteration is quite small, amounting to about $36,000 for nonresidential projects and only $7,000 for residential projects. Note also that a large proportion of the nearly 3 million projects are accounted for by these additions and alterations. There is no doubt that some of the projects in the nonresidential class are large additions that could be slanted to include multi-hazard shelter but for the most part these projects are too small to be of interest in designing a shelter incentive program. Accordingly, the first step in reconciling the data has been to eliminate the additions and alterations from both sets of data. In the case of the Dodge data, the valuation represented by the Census line items was removed proportionately from the various categories.

TABLE 2.2

1983 BUILDING PERMIT DATA*

USE CLASS	BUILDINGS	VALUATION (Million $)	AVERAGE PROJECT COST (Thousand $)
Amusement & Recreation	4,705	$ 772	$ 164
Churches, Other Religious	4,478	1,040	232
Industrial	19,135	5,830	305
Parking Garages	887	673	759
Residential Garages	190,359	990	5
Service Stations & Repair Garages	4,412	287	65
Hospitals & Institutions	1,819	2,357	1,296
Offices, Banks, Prof.	22,058	12,587	571
Public Works & Utility Bldgs.	2,765	827	300
Schools & Educational	2,209	987	447
Stores & Mercantile	36,953	7,380	200
Other NonResidential	119,987	1,544	13
Additions & Alterations	438,295	15,705	36
TOTAL NONRESIDENTIAL	848,062	$50,979	$ 60
One-Family Housing	901,000	$49,118	55
Multi-Family Housing	92,967	20,160	217
Nonhousekeeping Residential	3,150	3,082	978
Additions & Alterations	1,102,656	7,820	7
TOTAL RESIDENTIAL	2,099,773	$80,180	38
ALL BUILDINGS	2,947,835	131,159	44

*Buildings and valuation taken from References 3 and 4

The second reconciliation step was to convert the Census use classes into the Dodge categories, there being no basis for splitting up the Dodge categories. Some use classes are essentially the same as Dodge categories: Offices, educational, hospitals, and manufacturing. For the Dodge classification, "commercial", the Census use classes considered applicable were "Amusement and Recreation", "Parking Garages", "Service Stations and Repair Garages", and "Stores and Mercantile." The remaining use classes (Churches, Other Religious, Residential Garages, Public Works and Utility Buildings, and Other Non-residential) were assigned to the category "other nonresidential."

The resulting valuation comparison is shown in Table 2.3. The first data column shows the Dodge valuation from Table 2.1 modified by reducing each entry by its proportionate share of the Census record of additions and alterations. The second data column is taken directly from Table 2.2 by combining use classes as discussed above. It can be seen, as expected, that the Census valuation is less than the Dodge valuation for all categories save one. Investigation as to why the Census "Industrial" use class has a higher valuation than the Dodge "Manufacturing" category revealed that it is Census practice to include administrative buildings and other offices on industrial sites in the industrial category whereas Dodge would place these buildings in the office building category. The higher Census valuation could reflect this. However, one would expect the Census office building valuation to be depressed by a like amount. This does not appear to be the case. Indeed, the Census figure would equal the Dodge valuation if the 92 percent coverage of permit-issuing places is taken into account.

The sharply lower Census valuation for educational and health facilities most likely reflects the fact that permits are usually not required for school construction and other government-owned buildings. The "Other Nonresidential" category also is low, probably because many public works buildings are government owned. On the whole, the reconciliation of the two sets of data appears reasonable. Since the Dodge data is the more complete, it should be used in projecting the amount and kind of slantable construction that will be available for consideration in shelter incentive programs. However, the precision implied by the specific valuation figures is unwarranted. Hence, we have rounded the adjusted Dodge valuations to create the "average year" values shown in the final data column of Table 2.3.

TABLE 2.3

VALUATION COMPARISON
(Additions and Alterations Removed)

CATEGORY	DODGE VALUATION (Million $)	CENSUS VALUATION (Million $)	"AVERAGE YEAR" VALUATION (Million $)
Office Bldgs	13,603	12,587	13,600
Commercial	10,109	9,112	10,000
Manufacturing	4,032	5,830	4,000
Educational	4,516	987	4,500
Hospital & Health	6,392	2,357	6,400
Other Nonresidential	6,523	4,401	6,500
TOTAL NONRESIDENTIAL	45,175	35,274	45,000
One-Family Houses	56,234	49,118	56,000
Multi-Family Housing	21,589	20,160	21,500
Nonhousekeeping Residential	3,940	3,082	4,000
TOTAL RESIDENTIAL	81,763	72,360	81,500
ALL BUILDINGS	126,938	107,634	126,500

One further adjustment appears warranted. It will be noted in Table 2.2 that there are two nonresidential use classes that do not appear to offer significant opportunity for shelter production because the size of the average project is very small. These use classes are "Residential Garages" and "Other Nonresidential." Both classes have been incorporated in the "Other Nonresidential" category of Table 2.3. Their elimination from further consideration in projecting slantable construction would reduce the average-year valuation in this category by $2.5 billion and over 300,000 projects with an average cost of about $8,000 each would be dropped. This adjustment has been reflected in Table 2.4, which summarizes the nationwide average-year planning data.

In Table 2.4, the first data column presents the "average-year" valuation data from Table 2.3 except that the "Other Nonresidential" valuation has been reduced as discussed above. The deletion of the residential garages and other low-cost projects results in a new average cost in this category of $258,000. The other average costs in the third data column are drawn from Table 2.2 except for the "Commercial" category, which is derived from four use classes in the table. The number of projects in the second data column is obtained by dividing the valuation by the average cost per project. Similarly, the unit costs in the final data column are drawn from Table 2.1 and the floor areas derived by dividing the valuation by the unit cost. There are several assumptions implicit in this procedure, the most important of which are: (1) the deletion of additions and alterations from the Dodge valuations does not alter the unit costs (cost per square foot) in the various categories, and (2) the average project costs determined by the permit data applies as well to the additional construction not covered by permits.

2.7 Residential Developments

It will be noted in Table 2.4 that one-family homes constitute over 80 percent of the 1,212,050 "projects". However, it is commonly observed that most new one-family homes (detached dwellings, townhouses, etc.) are built for sale as part of a major residential development. The developers are usually required to provide paved streets, sidewalks, and lighting and often build community centers, clubhouses, and other common facilities as an integral part of the development. The existence of these major residential projects offers a significant mechanism for incorporating multi-hazard shelter into residential

TABLE 2.4

ADJUSTED AVERAGE-YEAR BUILDING DATA

CATEGORY	VALUATION (Million $)	NO. OF PROJECTS	AVERAGE COST (Thousand $)	FLOOR AREA (Million Sq.Ft.)	UNIT COST ($ per Sq.Ft.)
Office Buildings	$13,600	23,820	$ 571	187	$72.62
Commercial	10,000	51,545	194	265	37.78
Manufacturing	4,000	13,115	305	74	53.71
Educational	4,500	10,065	447	53	85.56
Hospital & Health	6,400	4,940	1,296	60	107.50
Other Nonresidential	4,000	15,500	258	54	73.74
TOTAL NONRESIDENTIAL	$42,500	118,985	$ 357	693	$61.83
One-Family Houses	$56,000	990,000	$ 57	1,417	$39.53
Multi-Family Housing	21,500	99,075	217	563	38.18
Nonhousekeeping Residential	4,000	4,090	978	57	70.67
TOTAL RESIDENTIAL	$81,500	1,093,065	$ 75	2,037	$40.18
ALL BUILDINGS	$124,000	1,212,050	$102	2,730	$46.69

construction since developers could incorporate neighborhood shelter efficiently into common facilities or into blocks or clusters of dwelling units. Moreover, the administration of a shelter incentive program would be simplified by the substitution of a relatively few large projects for the million or so dwelling units built annually.

Inquiry at F. W. Dodge Division, the Census Bureau, and the National Association of Home Builders failed to disclose any hard data on the number of one-family houses built as part of residential developments or the average size of such residential developments. However, some Census data was uncovered[5] that can be used to estimate these parameters for planning purposes. In 1983, of the roughly one million housing starts, the following pertain:

Built for Sale	67 percent
Built for Rent	2 percent
Built by Builder on Owner's Lot	14 percent
Built by Owner on Owner's Lot for Personal Use	17 percent
Total	100 percent

The two-thirds built for sale are likely to be built as part of a residential development. The most common professional judgment of those questioned was that "nearly all" would be in developments. Thus, a first-order estimate of the number of one-family houses in Table 2.4 that would be in residential developments is 650,000. Informal estimates of the size of the "typical" residential development (annual construction) ranged between 50 and 100 dwelling units. For convenience, we chose 65 units, thus projecting some 10,000 residential developments nationwide. For planning purposes, it is useful to keep these "projects", averaging nearly $4 million each in construction costs, separate from the 340,000 one-family houses built individually.

2.8 Multi-Family Housing

The category, "Multi-Family Housing" in Table 2.4 incorporates data on buildings with two or more dwelling units. Two-family residences (duplexes) and even three- and four-family houses are similar to one-family houses in many respects. Buildings with larger numbers of dwelling units are more nearly like office buildings, schools, and the like. Present blast-slanting techniques are most applicable to these larger buildings. Therefore, it may be useful in designing shelter incentive programs to distinguish between buildings with five or more dwelling units and smaller residential structures. The Census data permits one to do this. The relevant data are shown in Table 2.5. Note that buildings with five or more units constitute less than half the buildings although they represent nearly 80 percent of the valuation. The average building of this type contains about 13 units and costs about $373,000 or about $30,000 per dwelling unit.

2.9 Construction in Risk Areas

The building permit data collected by the Bureau of the Census are summarized by location outside of Standard Metropolitan Statistical Areas (SMSAs), inside SMSAs, and inside the central cities within these SMSAs. Unfortunately, the construction data are not available directly for urbanized areas, which, as noted in Section I, are a good representation of risk areas, locations where the policy in some shelter incentive programs would be to specify all-effects shelter (blast shelter). However, the amount of new construction in urbanized areas can be estimated reasonably well in proportion to the population residing there. The results are shown in Table 2.6. Of the total 1980 population of the U.S., 29 percent lived in central cities within SMSAs. The urbanized areas that include these central cities contained 61 percent of the U.S. population. The SMSAs, which extend to county boundaries beyond the urbanized areas, contained 75 percent of the population. The remaining 25 percent resided outside the metropolitan areas.

With respect to construction valuation, which is directly related to the amount of floor area produced, the second column in Table 2.6 shows that construction occurs at a higher rate in the cities than in the countryside. Thirty-nine percent of the valuation occurred in central cities, although they represent only 29 percent of the population, and 87 percent occurred in SMSAs. Only 13 percent occurred outside of metropolitan areas. If the amount inside SMSAs but outside their central cities is allocated to urbanized areas in proportion to population, 73 percent of construction valuation would be in urbanized areas. Since construction is skewed toward population centers, this procedure probably underestimates the amount of construction in urbanized areas somewhat.

TABLE 2.5

1983 MULTI-FAMILY HOUSING*

CATEGORY	VALUATION (Million $)	%	PROJECTS	%	AVERAGE COST (Thousand $)
Two Units	$ 1,971	9.8	28,758	30.9	$ 68
Three-Four Units	2,374	11.8	21,753	23.4	109
Five or More Units	15,815	78.4	42,456	45.7	373
TOTAL	$20,160	100.0	92,967	100.0	$217

*Based on data in Reference 3.

TABLE 2.6

LOCATION OF 1983 CONSTRUCTION*

Location	1980 Population (Percent of total)	Construction Value (Percent of total)	Buildings (Percent of total)
Inside Central Cities	29	39	21
Inside Urbanized Areas	61	73	56
Inside SMSAs	75	87	72
United States	100	100	100

*Construction Value and Buildings include nonresidential, nonhousekeeping residential, and multifamily housing with 5 or more units.

The final column in Table 2.6 indicates that the larger buildings are in the population centers as might be expected. The 39 percent of valuation in central cities is in only 21 percent of the buildings. Conversely, the 13 percent of valuation outside SMSAs represents about 28 percent of the new buildings. Overall, a reasonable planning estimate is that about three-quarters of new floor space will be built in risk areas (urbanized areas) but that this space will occur in somewhat over half of all buildings.

Note that the data presented in Table 2.6 covers nonresidential buildings, nonhousekeeping residential buildings, and multifamily housing with 5 or more units. If one assumes that single-family housing developments are similarly distributed between urbanized areas and the remainder of the country, it is possible to summarize the average year's construction outlook for the major building categories of interest in designing a shelter incentive program and, with certain occupancy assumptions, project the potential yield of shelter space. This projection is shown in Table 2.7 for urbanized areas and in Table 2.8 for the remainder of the country.

In Table 2.7, the "valuation" figures are 73 percent of those in Table 2.4, except that the base valuation for One-Family Developments is two-thirds the valuation shown in Table 2.4 for One-Family Houses and that for Multi-Family Housing is 78.4 percent of the value in Table 2.4, based on the data in Table 2.5. Similarly, the numbers of projects in the second column are 56 percent of the values in Table 2.4 with the exceptions noted above. Floor area has been proportioned in the same fashion as the valuation column on the basis that unit costs are unchanged.

The final two columns in Table 2.7 introduce a new concept--that of occupancy. Various national standard-setting organizations have developed model building codes that are widely referenced in local building codes. These codes establish presumed occupancies in terms of square feet per occupant in a proposed building for the purpose of sizing exits, support systems, and safety features. Examples are the Basic Building Code of the Building Officials and Code Administrators International and the Building Exit Code of the National Fire Protection Association. The occupancy assumptions shown in Tables 2.7 and 2.8 for nonresidential construction are drawn from these sources or from building construction data such as the school construction

TABLE 2.7

ANNUAL CONSTRUCTION AND SHELTER IN URBANIZED AREAS

BUILDING CATEGORY	VALUATION (Million $)	PROJECTS (Number)	AVERAGE COST (000 $)	FLOOR AREA (Million Sq. Ft.)	OCCUPANCY ASSUMPTION (Sq. Ft. per Person)	POTENTIAL SHELTER (000s)
Office Bldgs	$ 9,930	12,340	744	137	100	1,370
Commercial	7,300	28,860	253	193	60	3,220
Manufacturing	2,920	7,340	398	54	100	540
Educational	3,280	5,640	582	39	80	490
Hospitals & Health	4,670	2,770	1,686	44	190	230
Other Nonresidential	2,920	8,680	336	39	100	390
TOTAL NONRESIDENTIAL	31,020	66,630	470	506	81	6,240
One-Family Developments	27,400	5,600	4,891	693	650	1,060
Multi-Family Housing	12,310	25,360	486	322	100	3,220
Nonhousekeeping Residential	2,920	2,290	1,275	42	100	420
TOTAL RESIDENTIAL	42,630	33,250	1,282	1,057	225	4,700
ALL BUILDINGS	$73,650	99,880	737	1,563	143	10,940

TABLE 2.8

ANNUAL CONSTRUCTION AND SHELTER OUTSIDE URBANIZED AREAS

BUILDING CATEGORY	VALUATION (Million $)	PROJECTS (Number)	AVERAGE COST (000 $)	FLOOR AREA (Million Sq. Ft.)	OCCUPANCY ASSUMPTION (Sq. Ft. per Person)	POTENTIAL SHELTER (000s)
Office Buildings	$ 3,670	10,480	350	51	100	510
Commercial	2,700	22,685	119	72	60	1,200
Manufacturing	1,080	5,775	187	20	100	200
Educational	1,220	4,425	276	14	80	180
Hospitals & Health	1,730	2,170	797	16	190	80
Other NonResidential	1,030	6,820	158	15	100	150
TOTAL NONRESIDENTIAL	11,480	52,355	219	188	81	2,320
One-Family Developments	10,130	4,400	2,302	252	650	390
Multi-Family Housing	4,560	19,920	229	119	100	1,190
Nonhousekeeping Residential	1,080	1,800	600	15	100	150
TOTAL RESIDENTIAL	15,770	26,120	604	386	223	1,730
ALL BUILDINGS	$27,250	78,475	347	574	142	4,050

data discussed in Section I. For residential construction, multi-family housing and nonhousekeeping residential buildings (hotels, motels, etc.) are arbitrarily assigned the occupancy associated with office buildings. One-family developments, however, are assumed to be occupied by the average household size (2.9 persons) found in the 1980 census.

Then, if a shelter incentive program were to induce shelter for the assumed occupants of new buildings, the potential annual shelter yield could be nearly 11 million spaces in urbanized areas, as shown in the final column. This, of course, is not a prediction of program performance but rather an indication of the possible contribution of a program based on the slanting of new construction to shelter the occupants.

In Table 2.8, the valuation and floor area entries are 27 percent and the projects 44 percent of the Table 2.4 values, with the exceptions already noted above. Combined, the factors used in the two tables add to 100 percent. Comparing the two tables, it is noted that the projects considered slantable number nearly 100,000 in urbanized areas and nearly 80,000 elsewhere. However, the projected valuation and floor area in urbanized areas is nearly three times that outside these areas. As a consequence, the average cost (size) of projects in urbanized areas is about twice the size of those elsewhere. With respect to the need for shelter, the projected annual shelter yield in urbanized areas, if built where the need existed, could satisfy the need in about 15 years. The pace of construction outside of urbanized areas would not provide enough new shelter over a period of 25 years. However, since fallout shelter is the likely requirement here, the potential shelter might augment the existing fallout shelter inventory in a much shorter period of time. In any event, it is clear that even a mandatory shelter program must be considered a long term commitment as it is in many European countries as well as the Soviet Union.

2.10 Regional Distribution of Construction

The regional distribution of building construction is of considerable interest in the design of shelter programs that tie the creation of shelter protection to the pace of new construction. A program that promises to satisfy the need for shelter nationwide over a period of years could leave shelter deficits in some regions of the country while creating an overabundance of shelter elsewhere. The Bureau of the Census data exhibited in Table 2.9 indicates that the regional distribution of construction is very uneven. Nearly two-thirds of the value of nonresidential construction, nonhousekeeping residential construction, and large (5 or more units) multifamily housing construction occurred during 1983 in the "sunbelt" States represented by Regions 4, 6, and 9. In the 1980 census, the sunbelt States accounted for 40 percent of the population. Although the sunbelt population is growing, the rate of new slantable construction is even higher. On the other hand, the Northeast (Regions 1, 2, and 3), with 28 percent of the Nation's people, had only 16 percent of the slantable construction. The Midwest, with 20 percent of the population, had only 11 percent of the new construction. Clearly, these imbalances in the amount of slantable construction must be considered in projecting program accomplishments.

2.11 Basement Distribution

Another factor in planning for the incorporation of shelter in new construction is the prevalence of basements in various parts of the country. Full slanting against all weapons effects can be accomplished economically only in basements. If a building is being built with a basement, the modifications to produce all-effects shelter are not costly. If a basement must be introduced, there is an increase in cost. Basements are included in new buildings for several reasons, of which the most important are (1) savings in costs of heating and cooling, and (2) gaining usable space in crowded areas or where land costs are high. The first of these reasons is a strong motivator in the northern part of the United States but less so in the sunbelt areas. The second becomes important in central cities. Typically, large buildings are more likely to have basements than single-family residences, especially in the South.

Neither the Bureau of the Census permit data nor the Dodge construction outlook reports provide information on the prevalence of basements. Therefore, we turned to the National Facility Survey (NFS) inventory of existing buildings. The NFS computer printout covers all surveyed buildings containing public fallout shelter and has an entry for the number of basement spaces in the building. It was assumed that if no basement spaces were listed, the building had no basement. A random sample of 100 buildings in each State was drawn and the fraction with basements recorded. The sampling was done

TABLE 2.9

REGIONAL DISTRIBUTION OF 1983 CONSTRUCTION*

Federal Region	Construction Valuation (Million $)	Construction Valuation (Percent)	Buildings With Basements (Percent)
1	1,927.1	4	81
2	2,668.2	5	81
3	3,771.5	7	80
4	10,645.2	21	53
5	5,478.3	11	86
6	11,266.0	22	66
7	1,572.2	3	85
8	2,117.5	4	91
9	10,219.1	20	59
10	1,672.9	3	71
Total	51,338.0	100	75 (Average)

*Includes nonresidential, nonhousekeeping residential, and multifamily housing with 5 or more units.

twice and the results averaged for each Federal Region. The percentages are shown in the final column of Table 2.9. Nationwide, about 75 percent of large buildings have basements. The four Regions with less than the national average are the sunbelt regions plus the Pacific Northwest. Note, however, that the majority of buildings surveyed in the sunbelt Region 4 (South) have basements.

2.12 Size Distribution of Slantable Construction

The data in Table 2.4 provides some insight into the average size of buildings in the various construction categories. The essential information is summarized in Table 2.10, omitting one-family homes and multi-family houses with less than 5 dwelling units. These averages, however, do not provide a sufficient basis for the design of shelter incentive programs. For example, the Alabama shelter law exempts state buildings costing less than $50,000 from its requirements. The Arizona shelter law exempts state buildings costing less than $100,000 automatically and exempts buildings up to a cost of $450,000 upon request. Establishing a minimum project cost can be justified on several grounds: (1) providing shelter in a small structure can be very costly; (2) not much shelter would be acquired; (3) the shelters gained would hold only a few persons; and (4) eliminating small projects would reduce the costs of administering a shelter law. One should understand, however, how much shelter is foregone when a minimum cost is proposed. Average costs must be augmented by some idea of the distribution of building size and cost around the mean or average.

It can be seen from the penultimate column in Table 2.10 that the average project cost by construction category ranges from about half the overall average to about three and one half times the overall average, a range of a factor of seven. Since there will be some commercial structures costing considerably less than the average for that category and some hospitals costing considerably more than the average for hospitals, the range of project costs can be quite great. Further, it will be recalled that in arriving at the data in Table 2.4, we eliminated alterations and additions, residential garages, and other categories of very small projects. Even so, the final column in Table 2.10 shows that a majority of the remaining buildings cost less than the overall average. Of course, the few large buildings contribute very substantially to total valuation and floor area.

TABLE 2.10

AVERAGE BUILDING SIZE AND COST*

Category	Average Floor Area (sq. ft.)	Average Cost ($)	Fraction of Average Cost	Cumulative Fraction of Buildings
Commercial	5,135	194,000	.52	.31
Other Nonresidential	3,500	258,000	.69	.40
Manufacturing	5,680	305,000	.81	.48
MultiFamily Housing (5 or more units)	9,750	372,000	.99	.74
Educational	5,225	447,000	1.19	.80
Office Buildings	7,860	571,000	1.52	.94
Nonhousekeeping Residential	13,840	978,000	2.61	.97
Hospitals and Health	12,055	1,296,000	3.46	1.00
Overall Average	6,600	375,000		

*In urbanized areas, average floor area and cost are 30 percent greater; outside the urbanized areas, they are only 61 percent as large. See Tables 2.7 and 2.8 for average project costs.

The skewed distribution seen in the final column of Table 2.10 is characteristic of economic variables, such as income, wealth, size of industrial plants, numbers of employees, and the like. Econometricians fit various kinds of binominal distributions to their data as well as Pareto, lognormal, and similar distributions. The size distribution of each construction category in Table 2.10 could be established by detailed examination of the individual project records maintained by the F. W. Dodge Division but this analysis lies beyond the scope of this study. Rather, we have reviewed the basis for similar analysis of economic variables[6] and have constructed an arbitrary distribution that is likely to be representative of the size variation of building projects in the region where decisions might be made to exempt or exclude projects costing less than a certain value. Our assumed distribution is shown in Table 2.11.

The values in Table 2.11 define the assumed cumulative distribution as a function of the average cost per project in a given construction category. Thus, the values in the first column are to be multiplied by the average cost per project to determine the cumulative cost class, "All projects costing less than x dollars." For example, the average cost per project for the "commercial" category is $194,000. Then, the first line of Table 2.11 means that commercial buildings costing less than $48,500 (one-quarter of the average) comprise nine percent of the buildings in the category and two percent of the total valuation in the category.

Alternatively, suppose one were considering exemption of all new buildings costing less than $100,000. For commercial buildings, this cutoff level is 52 percent of the average cost. Interpolating in Table 2.11, one finds that this exemption would eliminate about 25 percent of commercial buildings and about 10 percent of the valuation or floor area. For all other construction categories, the impact would be less since their average cost is higher.

2.13 Building Ownership

An important consideration in the design of incentive programs is the nature of the building ownership. For example, tax incentives appeal only to owners who must pay taxes. There is little data available on the owners of the buildings built in 1983. Building permits are reported to the Bureau of the Census as publicly or privately owned. However, many governments and

TABLE 2.11

ASSUMED DISTRIBUTION OF COST PER BUILDING

Cumulative Cost Class (Less than)	Fraction of Buildings	Fraction of Total Valuation
.25	.09	.02
.50	.24	.09
.75	.43	.24
1.00 (Average)	.63	.43
1.25	.79	.63
1.50	.89	.79
1.75	.95	.88
2.00	.98	.95
2.25	.992	.98
2.50	.998	.993
2.75	.999	.998
3.00	1.000	1.000

public bodies such as school districts are not required to obtain permits. Moreover, the Census instructions are to report as publicly owned all buildings owned by a governmental body from the outset of construction, not housing to be sold on completion to a Local Public Housing Authority or housing built by nonprofit organizations or under the various Federal housing programs. Therefore, the available data is not very useful.

The most complete data source on the ownership of buildings of the kind that could have been slanted to contain multihazard shelter is FEMA's National Facility Survey (NFS). The NSF All-Facility Summary of August 31, 1981 shows the following ownership participation in existing buildings:

Owner	Percent of Facilities
Federal government	5
State Government	6
Local government	15
Private	74

Thus, if ownership of buildings built in the past is any clue to the likely ownership of buildings to be built in the future, governments will own 26 percent and private organizations and individuals, 74 percent.

These data are the best available for this study. It is not fully adequate because private ownership includes both nonprofit and profit-making entities. Nonprofit participation probably is a small fraction of private ownership. The valuation comparison in Table 2.3 offers some basis for estimating the dimensions of nonprofit ownership. It was noted earlier on that the low Census valuation for the educational category can be accounted for by the fact that permits are not usually required for public schools. The 2,209 buildings in this category that required building permits were almost entirely of nonprofit ownership. Likewise, the 4,478 buildings shown in Table 2.2 as "Churches and Other Religious" are clearly nonprofit. Together, these two categories constitute about 6 percent of nonresidential buildings built in 1983.

An inspection of Table 2.3 also reveals that the Census valuation for hospitals and health is only about one-third of the Dodge valuation, indicating the strong role of government in this area. The 1,819 buildings that did require permits include hospitals and nursing homes built by nonprofit entities such as churches, unions, fraternal organizations, and the like. However, many nursing homes and other facilities are owned by taxable entities. Therefore, not all in this category can be classed as nonprofit.

Non-profit organizations, as defined by Section 501 of the Internal Revenue Code, include not only religious, educational, and charitable groups but also civic leagues, labor unions, chambers of commerce and business associations, fraternal societies, social and recreational clubs, veterans groups, beneficiary insurance associations, and cooperatives. These groups build some of the office buildings and a substantial part of the multi-family housing. Recreational facilities and meeting places also are owned by nonprofit organizations. No firm data on the amount of this construction was found but it could amount to four or five percent of the buildings built annually. Added to churches and schools, a figure like 10 percent of buildings is not unreasonable.

With respect to valuation, churches, schools, hospitals, and office buildings have higher than average project size and cost. On the other hand, commercial, industrial, and other nonresidential construction associated with private for-profit entities have lower-than-average cost, according to Table 2.10. Thus, one may anticipate that governments and nonprofit institutions will have a somewhat larger share of construction valuation than the foregoing discussion of buildings would indicate. For program design purposes, we propose to use the ownership shares shown in Table 2.12. These shares apply to all building construction except one-family developments, which are entirely private for-profit ownership.

TABLE 2.12

ASSUMED BUILDING OWNERSHIP*

Owner	Buildings (percent)	Valuation (percent)
Federal Government	5	7
State Government	5	7
Local Government	15	18
Private NonProfit	10	12
Private For-Profit	65	56

*Applies to nonresidential, nonhousekeeping residential, and multi-family housing. One-family developments are almost entirely private for-profit ownership.

SECTION II REFERENCES

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2. 1985 Dodge/Sweet's Construction Outlook, McGraw-Hill Information Systems Company, October 1984.

3. Housing Units Authorized by Building Permits and Public Contracts: Annual 1983, Bureau of the Census, U.S. Department of Commerce, C40-83-13, June 1984.

4. Non-Residential and Residential Construction Activity, Computer Printout Run 4, MBP-939, Bureau of the Census, U.S. Department of Commerce, 1983.

5. Personal communication from Sherwin Weinstock, Bureau of the Census.

6. Klein, Lawrence R., An Introduction to Econometrics, Prentice-Hall, Inc., 1962.

SECTION III

SLANTING CRITERIA AND COSTS

3.1 Shelter Design Parameters

A shelter incentive program will require the inclusion of protective features in the design of new structures to meet specific criteria. The objective of a shelter incentive program is to improve the lifesaving effectiveness of public shelter by the routine incorporation of protective characteristics into the design of new buildings and other structures without adversely affecting the utility, cost or function of the project. This procedure is called "slanting." Slanting adds the protective function to the other criteria normally considered in the design of structures.

In order to provide protection against nuclear weapons effects, two types of shelter are required; all-effects and fallout. All-effects shelters are designed to protect against the blast, thermal, initial nuclear radiation (INR), and fallout gamma radiation resulting from a nuclear detonation. They also protect occupants against the common hazards discussed in Section I. All-effects shelter would be required for locations likely to be subjected to blast and thermal effects in a nuclear attack. For emergency planning purposes, FEMA has designated a number of locations as "high risk" areas that are considered more likely to receive the direct effects of a nuclear attack than are other locations. As one moves away from the nuclear burst point and out of the high risk areas, these direct effects diminish. The threat to the populace outside of the high risk areas then becomes limited to radiation from fallout particles which may be carried by the wind many miles away from the attacked area. Fallout particles emit gamma radiation that is harmful to humans. Thus, fallout shelters would be required for protecting the populace in locations outside of designated high risk areas.

The levels of protection that can be provided by the two types of shelter are discussed below:

a. Fallout Protection. FEMA and its predecessor agencies have developed standards for public fallout shelter which establish the minimum level of protection as being a Protection Factor of 40. The Protection Factor (PF) is a numerical value which expresses the relation between the amount of fallout gamma radiation that would be received in a protected location and the amount that would be received if unprotected in the same location.

It is recognized that no amount of radiation exposure will be beneficial to one's lifespan. On the other hand, given a fallout radiation environment, it is not economically or technically feasible to attempt to shield out all the radiation. The minimum level of PF 40 was established as a compromise between what was desirable and what was practical to attain. Significant numbers of existing buildings and other facilities had PF 40 protection inherent in the design and therefore could be used in an "interim" period to help protect the American population until such time when better shelter could be made available.

A desirable radiation shielding objective would be to keep the radiation insult on shelter occupants below a level that would induce radiation sickness. Radiation sickness is not likely to occur in most humans unless the accumulated dose is 50 rems or more. A whole-body dose in the range of 100-200 rems will result in a certain amount of illness with little fatalities. For doses between 200 and 600 rems, the probability of near-term survival is good at the lower end but poor at the upper end. In a large-scale urban industrial nuclear attack on the United States, most shelter occupants in PF 40 shelters located outside of target areas would survive, but some would suffer radiation illness. Design analyses procedures and methodologies to determine fallout protection have been in existence for a number of years and are reflected in FEMA publications.[1,2]

When designers have an opportunity to "create" shelter in new buildings undergoing design, consideration should be given to increasing the minimum level of fallout protection to PF 100. This not only improves the shelter occupants' chances for survival and reduces the likelihood of their incapacitation from radiation sickness, it can also be attained in most cases at only a slight increase above the cost of PF 40 space. The opportunity for creating better protection at a low incremental cost that may also provide the building owner with financial benefit (i.e., shelter incentive) should not be wasted. Although current FEMA policy accepts a PF of 40 for inherent shelter space, we believe that a higher PF is appropriate for incentive programs as it is in the Emergency Operating Center program.

b. <u>All-Effects Shelter</u>. Shelters located in high risk areas should be all-effects shelters. Virtually all such shelters will be located in the basements of buildings or other structures because low-cost blast protection can only be obtained in belowground locations. Where high water table, subsurface rock, or expansive soil conditions exist, such basements can be built partially or wholly aboveground by inducing an "artificial" basement (see Section 3.4 for a discusssion on costs associated with inducing a basement). Any openings to the shelter area (e.g., doors, stair wells, ventilation ducts, elevator shafts, etc.) must be capable of being sealed off to preclude the blast wave from entering the shelter area.

Standards for all-effects shelters have not been developed by FEMA or its predecessors. All-effects shelters have more structural requirements than fallout protection and are, therefore, more costly to construct. The design methodology for providing blast protection exists[3] but there has been relatively little experience on slanting designs for all-effects shelter. The major sources of guidance on blast slanting for all weapons effects are several feasibility and case studies by H. L. Murphy, J. R. Rempel, and J. E. Beck.[4] Shelter designs in these studies exist for design overpressures of 15, 20, and 30 psi. These are regarded as a suitable range for design options. Figure 1.2 in Section I shows the distribution of the population with overpressure for the FEMA-DCPA TR-82 attack, which is currently being utilized by FEMA as the basis for the population protection program in the United States. The curve in Figure 1.2 can be used to judge the lifesaving effectiveness of shelters of varying hardness against direct weapons effects. This is a cumulative distribution, e.g., over 80 percent of the population to the TR-82 attack is likely to experience less than 20 psi. About 90 percent of the population is likely to experience 30 psi or less. As can be seen from Figure 1.2, the curve rises steeply at the lower overpressures and flattens out into an area of diminishing returns at higher overpressures. Clearly, shelters capable of resisting 100 psi or more would be ideal, but they would be too costly to consider. Slanting costs increase as blast resistance increases and there is believed to be a sharp jump in cost in the neighborhood of 50 psi where ground shock isolation becomes a major problem. Thus, a cost-effectiveness tradeoff must be made with an upper limit of 30 psi being established as the cutoff.

It should also be noted that "design overpressure" falls short of the overpressure at which casualties would begin to occur in the sheltered population, which is the layman's understanding of the meaning of a "30-psi shelter." For system performance analysis, a useful parameter is Median Lethal Overpressure, which is associated with an even higher overpressure than that identified with the onset of casualties. The latter criterion will occur at an overpressure that ranges from 1.3 to 1.8 times the design overpressure, depending on details of the slanting design. Thus, one-half of those in an all-effects shelter designed for 30 psi might experience fatalities at overpressures ranging from 39 to 54 psi.

c. INR. INR is the radiation emitted from a nuclear explosive reaction and the resulting residues within the first minute after a nuclear explosion. It consists of neutrons and gamma rays emitted almost instantaneously as well as gamma rays emitted by the fission products in the rising cloud. Using data from The Effects of Nuclear Weapons,[5] we calculated the total INR outside radiation dose anticipated at the location where 30 psi from a 1 MT surface burst will exist to be about 11,500 rem, with approximately 6.3 percent being neutrons.

Shielding against INR is somewhat different from shielding against gamma radiation. Although a methodology has been developed for the latter, very little has been published with respect to INR shielding. Our analytical approach involved a simple structure schematization based on the work of L. V. Spencer and C. M. Eisenhauer.[6,7] The components of INR include: (1) gamma radiation from the fission products emitted from the developing and rising fireball during the first minute (FPG); (2) secondary gamma radiation produced by the interaction of neutrons with the air (ASG); (3) neutrons emitted from the detonating weapon (N); and (4) gamma radiation produced by the neutrons in interactions with the materials of the walls and floors of the structure (NGAM). Each of these components was treated separately in calculating the attenuation through the structure because of their differing nature, energies, and angular distributions. The methodology for computing INR attenuation involves calculating and summing reduction factors for each of the above components. The procedures were developed in accordance with guidance received from Messrs. Spencer and Eisenhauer and are presented in Appendix A.

INR can enter an all-effects shelter through the overhead concrete slab and through shelter openings, primarily entranceways. Previous INR studies conducted by C. K. Wiehle and others indicated that for purposes of analysis, INR through an entryway can be separated into three phases: the entrance reduction factor, entranceway bend and corridor attenuation, and barrier attenuation. Methodologies for calculating these phases currently exist.[8,9] An approach to handling the INR threat that appears reasonable is to allocate half of the dose as coming through the overhead slab and half the dose coming through the openings. Thus, if the total INR dose is to be limited to 200 R, then the concrete slab over the all-effects shelter should be thick enough to attenuate to 100 R or less and entranceways shielded through bends, corridor attenuation, and barrier attenuation to reduce the INR insult to no more than 100 R.

An analysis was made using the techniques described in Appendix A to determine the slab thickness required to attenuate the INR. The building characteristics are illustrated in Figure 3.1 along with the analysis results. The latter indicate that a slab thickness of approximately 14 inches will be required to attenuate the INR from a 1 MT surface burst weapon at 30 psi to a level of 100 R. At lower overpressures, a lesser slab thickness would be required. Smaller yield weapons generally produce higher levels of INR for the same overpressure. For example, a 200 KT weapon ground burst is likely to produce an INR of 12,300 R at the 20 psi range and 36,800 R at the 30 psi range. Figure 3.1 indicates that a basement would require a slab thickness of 17 inches to attenuate the INR produced by a 200 KT ground burst weapon to 100 R of 20 psi and about 25 inches to attenuate the INR produced by a 200 KT weapon at 30 psi to the same level.

Reference 4 contains charts for simply-supported one-way slabs that identify the slab thickness needed for varying span lengths to resist given overpressures. Using these charts, which are also reproduced in Reference 3, a designer can select a slab thickness and the amount of reinforcing steel necessary to resist the design blast overpressure. The thickness can be adjusted to accommodate the other nuclear weapons effects, primarily that of INR, thus producing a "balanced" design.

In using the balanced design concept, one could specify that the minimum slab thickness required for any all-effects shelter should not be less than 14 inches (i.e., the slab thickness necessary to attenuate INR for a 1 MT ground burst at 30 psi). Using the overhead slab design curves generated by Murphy and Beck for a 1 MT 30 psi environment, a slab thickness of 18 inches would be required for a 20-foot simply-supported concrete slab reinforced

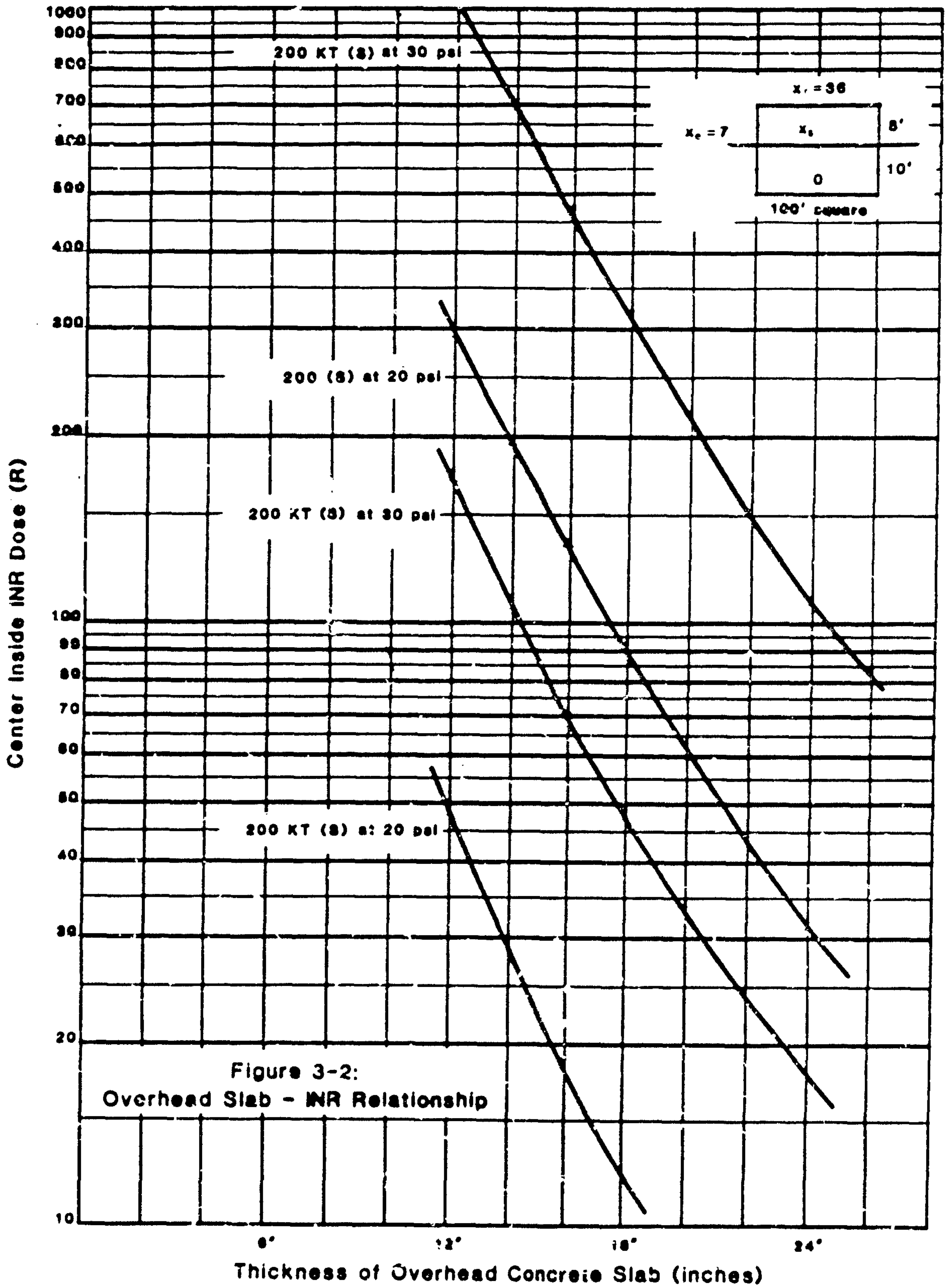

Figure 3-2:
Overhead Slab - INR Relationship

with ordinary structural steel at 2 percent.[2] This thickness would attenuate the INR from a 1 MT surface burst at 30 psi to less than 50 R. It also would be very effective for smaller weapons (e.g., reduces INR to 90 R for a 200 KT weapon at 20 psi). A 12-foot span length requires a 12-inch slab to resist the blast effects from a 1 MT weapon at 30 psi. However, because of the balanced design principle, it would be necessary to increase the slab thickness to 14 inches so that the slab will attenuate INR as well as resist the design blast loading.

3.2 Shelter Standards

Any shelter incentive program requires that shelter standards be established that can be utilized by architects and engineers to incorporate protective features in the design of new buildings. These standards must contain the shelter design criteria for both fallout and all-effects shelters. Appendix B to this report contains suggested shelter standards for inclusion in a shelter incentive program. The format of these standards is based primarily on FEMA publication TR-87.[10] Changes were made in the areas concerning: (1) need for emergency power generators to operate ventilation and emergency lighting for the shelter area; (2) need for EMP protected equipment; (3) need for water containers and chemical toilets; and (4) need for incorporating blast, thermal, and INR criteria. The shelter standards provided in Appendix B would be applicable for any of the incentive program options considered in this study. The protective standards offered in Appendix B are discussed in Section VI.

3.3 All-Effects Shelter Costs

Unlike fallout protection, which may be inherent in the design of many types of structures, all-effects shelters usually require specific actions by building designers to strengthen the various structural elements (e.g., walls, overhead floor slabs, and doors) to resist the dynamic loadings resulting from a nuclear explosion. Buildings usually have a reserve strength (i.e., a built-in safety factor) to safeguard against collapse when actual forces exceed design values, but this reserve strength typically is not sufficient to withstand the blast forces that may exceed design values by several times. Most existing buildings will collapse at overpressures greater than 10 psi.

While a methodology for designing all-effects shelters is available, there has been little construction of such shelters for general population protection purposes. Most of the construction that has taken place has been primarily for military purposes and for emergency operating centers rather than personnel shelters. In the mid to late 1960s, the Federal Government embarked on a number of programs which encouraged the incorporation of fallout protection in the design of new buildings. Similar programs for all-effects shelter were never implemented. As a result, there is a paucity of data available on construction costs for all-effects shelters incorporated into new construction.

As noted earlier, Murphy et al conducted a series of feasibility studies on techniques for slanting the design of basements in new buildings to provide protection against blast, and initial nuclear, thermal and fallout gamma radiation.[4] Their report was intended as a guide for architects and engineers who may be called upon to design all-effects shelter in the basement of a new building. The report not only provided detailed design procedures for concrete slabs to be placed over the all-effects shelter area, but also included estimates of the incremental shelter costs for modifying the basement designs of several existing buildings to provide protection for 15, 20, and 30 psi overpressures. All-effects shelter cost estimates extracted from this report are presented in Table 3.1 with cost data updated to reflect 1983 dollars. See Appendix C for details.

The data indicates that, as expected, all-effects shelter costs will vary with the level of protection provided. As design blast overpressures increase, shelter construction costs will rise. Costs for shelters designed to resist 15-psi overpressure ranged from $17.12 to $21.19 per square foot of shelter area depending on the size of the shelter. Large shelters generally have lower unit costs than small shelters. When design overpressures are increased to 20 psi, shelter costs ranged from $18.74 to $22.67 per square foot of shelter area. A further increase of design overpressure to 30 psi increases the range of shelter costs from $23.09 to $27.72 per square foot. It should be noted that Murphy et al analyzed only four buildings to arrive at their detailed shelter cost estimates for slanting basement designs. Admittedly, this is not an adequate data base, but they are the only data currently available on basement all-effects shelter slanting costs that

TABLE 3.1

SUMMARY OF ALL-EFFECTS SHELTER COST ESTIMATES
(1983 dollars)

Building	2A	3A	3Am 1/	4A
Shelter Area (Sq.ft.)	3,378	13,598	16,351	130,522
Design Overpressure				
15 psi (cost/sq.ft.)	$21.19	$18.42	$17.37	$17.12
20 psi (cost/sq.ft.)	$22.67	$20.21	$18.74	$19.40
30 psi (cost/sq.ft.)	$27.72	$25.54	$23.09	--

1/ Building 3Am is identical to building 3A except for the addition of a mezzanine which provides for additional shelter area.

are applicable to a shelter incentive program. Additional research to expand this data base needs to be accomplished. Also required is further research on new and innovative design techniques and materials that will reduce all-effects shelter costs.

The study conducted by Murphy et al[4] also provided an insight as to how basement slanting costs are distributed into various cost categories. The total all-effects shelter costs were broken down into four different cost categories -- structural, blast doors and closures, ventilation, and all other costs. The results are presented in Table 3.2. The data indicate that structural design modifications account for an average of 62-71 percent of the total shelter costs. Blast doors and closures account for an average of 11-13 percent of total cost. Ventilation costs account for an average of 12-20 percent and other miscellaneous costs account for 4-6 percent of the total shelter cost. Ventilation costs include the provision of emergency electric power. In general, these costs are consistent with the standards presented in Appendix B.

3.4 Cost of Inducing a Basement

On a national basis, approximately 75 percent of slantable buildings have basements. This varies from State to State. Those States located in the "sunbelt" generally have the lowest rate of basement construction (e.g., FEMA Region IV and Region IX have basements in 53 and 59 percent, respectively, of their buildings whereas States in FEMA Regions VIII, V, and VII have 91, 86, and 85 percent, respectively, of their buildings with basements). A considerable amount of excavation and grading is required to provide the proper foundation for large buildings. Therefore, the incorporation of a basement in the building design usually is not a large cost item. Cost data in the Means Catalog[11] indicate that construction costs in the sunbelt States average about 10 percent less than in the northern tier but it is not clear how much of this differential, if any, is due to a smaller incidence of basements. As an example, construction costs in Denver, where basements are usual, are about the same as in New Orleans, where basements are rare.

Basements usually provide the best location for multihazard protection but are not practical in areas of high water table, subsurface rock, or

TABLE 3.2

DISTRIBUTION OF ALL-EFFECTS SHELTER COST ESTIMATES
BY CONSTRUCTION CATEGORY

	15 psi Design Overpressure					20 psi Design Overpressure					30 psi Design Overpressure			
Building	2A	3A	3Am	4A	Avg.	2A	3A	3Am	4A	Avg.	2A	3A	3Am	Avg.
Structural Costs (%)	57	63	67	63	62	61	67	71	69	67	68	71	74	71
Blast Door Costs (%)	10	19	17	3	12	9	17	16	2	11	8	17	15	13
Ventilation Costs (%)	25	13	12	30	20	22	12	10	25	17	18	9	8	12
Other Costs (%)	9	4	4	5	6	8	4	3	4	5	7	3	3	4

NOTE: Numbers have been rounded and may not add to 100 percent.

expansive soil conditions. Where conditions preclude the construction of basements in a normal manner, they can be designed partially or wholly above-ground with earth berms placed around the shelter story, thus inducing an "artificial basement." The costs of inducing a basement through earth berming will have to be added in determining final shelter costs. Indications are that such additional costs could be significant.

The cost of a berm for all-effects shelter is affected by the requirement for a slope no greater than 1 vertical for each 3 horizontal. The slope of a berm for fallout protection can be much steeper and, hence, the volume of earth required can be reduced. For a shelter area of about 10,000 square feet, an all-effects shelter berm 10-ft. high will cost about $6 per square foot of shelter area, thus adding 20-25 percent to the unit costs shown in Table 3.1. This cost includes providing (1) an asphalt waterproof coating to the outside walls of the first story, (2) furnishing backfill material delivered to the job site, (3) placement of soil using earthmoving equipment and hand labor, (4) compaction using an air-powered tamper, and (5) seeding of the finished area to prevent erosion. Partial excavation to a depth of only 3 feet could halve the estimated cost. The prevalence of conditions in the sunbelt States that would make a bermed shelter story necessary is unknown.

3.5 Blast Closures

To be fully effective, all-effects shelter areas must have openings "sealed" to prevent air blast from entering, as specified in Appendix B. The unit costs summarized in Table 3.1 include such closures and guidance for the design of blast doors and closures will be found in Reference 4. The 30-psi doors used in these designs ranged in cost from $2,388 to $3,337 each. Since provision for off-street parking is an important peacetime use for basement space in large buildings, H. L. Murphy in Appendix C has designed and costed a sliding door for use in an underground parking area similar to building 4A in Table 3.1. The concrete vehicle door was 12 feet wide (clear span of 10 feet), 8 feet high (clear height of 7.5 feet), and 14 inches thick for INR attenuation. Door costs ranged from $2,971 for 15-psi blast resistance to $3,261 for 30-psi blast resistance. These costs include concrete, reinforcing steel, rollers, and rails for sliding the door closed. Additional costs of reinforcing the garage walls to carry the load applied by the door are not included. In general, door costs for parking garage application appear to be consistent with those entering into the case study results.

Closure panels would be required for the ventilation ducts that penetrate the cover slab over the basement all-effects shelter. Either automatic or hand closed blast closures are required at the ventilation intake and exhaust. Such closures are also required for ventilation ducts penetrating the shelter cover slab to prevent the air blast from entering the shelter area. For slanting the designs of all-effects shelters it is most desirable to reduce or eliminate the openings in the basement cover slab. This includes all types of openings such as ventilation ducts or elevators. For practical purposes, entry to the basement must still be provided, but if stairs or elevator shafts leading to the basement were located on the outer face of the building, considerable savings could be effected in shelter design. However, this may not be acceptable for normal everyday usage of the space and therefore, it may be necessary to resort to use of the blast closure devices noted previously.

3.6 Fallout Shelter Costs

During the mid to late 1960s, information was collected by the Office of Civil Defense (OCD) on buildings slanted for fallout shelter. Shelter costs varied from 1 to 3 percent of the total building cost. Based on this experience, OCD proposed an experimental fallout shelter grant program[12] in 1970 that included a proposed subsidy of $10 per shelter space having a Protection Factor of 40 or more. This subsidy was based on observed incremental costs of $7 to $10 as of 1969 (70 cents to 1 dollar per square foot).

During the past 15 years, construction costs have increased. To ascertain the magnitude of this increase, two data sources were reviewed:

a. Engineering News Record

The Engineering News Record (ENR) published by McGraw Hill provides a weekly construction news magazine that included Cost Indexes based on a 20 city average of construction costs.[13] Data extracted from ENR publications covering the period 1969 to 1985 is presented in Table 3.3. The Cost Index includes five cost categories (i.e., construction, building, unskilled labor, skilled labor, and materials) and values are provided for each category as of a given date. By comparing Cost Indexes for each category over a specific time period, one can determine a cost increase ratio. For example, referring to Table 3.3, the cost increase ratio for the period January 1969 to January 1983 for the materials category can be obtained by dividing 1593.69 by 548.91 to obtain 2.90. This indicates that materials that cost $1 in 1969 would cost $2.90 in 1983. The average cost increase ratio for the five ENR categories, as shown in the last column of Table 3.3, was found to be 3.15 (i.e., typical construction costs in 1983 were 3.15 times that they were in 1969).

b. Means Cost Data

The Robert Snow Means Company, Inc., Engineers and Estimators of Kingston, Massachusetts, publish "Building Cost Data" on an annual basis.[11] This document will be referred to as the "Means Catalog." The 1984 edition of Means Catalog includes data accumulated from actual construction job costs in 1983 and material dealers' quotations as of January 1, 1984 combined with January 1, 1984 labor rates. Therefore, the data in the Means Catalog for a given year is more representative of actual costs for the prior year. By comparing data in appropriate yearly editions of the Means Catalog, one can ascertain construction cost increases over the desired period. Data extracted from the Means Catalog suggests that during the period from 1969 to 1983, construction costs increased by a factor of 3.13.

3.7 Other Fallout Shelter Cost Considerations

Other factors that significantly affect the cost of providing fallout protection in a structure include the following:

a. Level of Protection

If consideration is given to increasing the level of fallout protection from a minimum level of PF 40 to a minimum level of PF 100, one can expect that this will impact on the shelter cost because of the increased shielding needed. For basement shelters that are completely below grade, the increased level of protection usually can be attained by increasing the overhead slab (i.e., ceiling over the basement) by 35-40 pounds per square foot in mass thickness. This is equivalent to adding 3 to 3½ inches of concrete to the basic slab thickness needed to provide a PF of 40. It also will be necessary to provide slightly larger columns and footings to support the additional dead load resulting from the increase in overhead concrete slab thickness.

TABLE 3.3

ENGINEERING NEWS RECORD MARKET TRENDS

COST INDEXES ENR 10 CITIES 1913 = 100

Category	YEAR 1/ 1/2/69	1/1/70	1/6/77	1/6/83	1/5/84	1/10/85	Cost Increase Ratio - 1983 ÷ 1969
Construction Cost	1216.3	1308.61	2499.1	3965.98	4108.74	4172.27	3.26
Bldg. Cost	764.42	802.44	1493.6	2361.07	2401.9	2424.23	3.09
Common Labor	2304.74	2574.14	4843.2	7822.11	8165.92	8363.55	3.39
Skilled Labor	1117.48	1243.73	2199.9	3484.75	3678.98	3768.32	3.12
Materials	548.91	532.95	1062.4	1593.69	1622.08	1603.41	2.90
						Avg.	3.15

1/ Cost data taken from Reference 13 for the dates shown.

Cost estimates for increasing the fallout protection from PF 40 to PF 100 range from 80 cents to $1.30 per square foot, depending on building size and configuration and number of stories.

b. Shelter Equipment

Included in normal building construction costs are those costs necessary to maintain comfort and habitability. While fallout shelters are generally austere in nature, consideration can be given to including equipment necessary to maintain a lifesaving capability. When people are placed in a shelter environment at 10 square feet per person, heat build-up may become a problem, depending on shelter location and time of year. Ventilation equipment is essential to maintaining a habitable environment. FEMA and its predecessor agencies have done much research and development in the area of shelter ventilation and special shelter ventilation equipment has been designed. These include a Packaged Ventilation Kit and a Kearny Air Pump (i.e., punkah fan) to provide sufficient outside air and air movement within the shelter. However, such equipment has not been mass produced and is not currently available in "over-the-counter" transactions.

A better alternative is to provide emergency power generators to operate either existing ventilation equipment or newly installed fans necessary to provide the required ventilation. The generators also provide for emergency lighting in the shelter area. In a post-attack environment, it is not likely that commercial electric power will be available and, therefore, use of emergency generators provides a feasible solution to the habitability problem. Furthermore, it also is attractive for those areas subjected to frequent natural disasters where power outages are common.

If such shelter equipment is to be provided, shelter costs will undoubtedly increase. The amount of increase is contingent upon the specific equipment provided and the design. It is difficult to develop precise shelter equipment costs without specifying a given design. However, for situations involving Packaged Ventilation Kits, data indicates costs on the order of 20 cents per square foot. Use of small emergency generators to meet emergency lighting for shelters may increase costs from 10 to 20 cents per square foot. Additional power for shelter ventilation may increase shelter costs from 80 cents to $1.50 per square foot, depending on building design and ventilation system used.

c. Basement Wall Exposure

Basement walls surrounding the fallout shelter area that are exposed and not completely belowground reduce the level of protection available to shelter occupants. The completely belowgrade basement utilizes the earth as well as the shelter walls and roof to attenuate the gamma radiation; the exposed basement walls normally do not have sufficient mass to protect the shelter area. Therefore, earth berms placed against the exposed portion of the basement wall are necessary to provide the needed shielding. However, this may increase the cost for providing fallout protection.

3.8 Shelter Cost Summary

Table 3.4 provides a summary of the anticipated costs for fallout and all-effects shelters discussed in this Section. One must recognize that the costs associated with incorporating shelter are directly related to a building's geometry. For example, multi-story buildings have a considerable amount of fallout protection located in the upper stories as an inherent part of the design. Little, if any additional costs are required to obtain fallout protection in this type of structure. However, basements are preferable for multi-hazard protection. All-effects shelter must be constructed belowground in order to be economically practical. Table 3.4 presumes basement shelter for both fallout and all-effects protection. If earth berms must be provided, their cost must be added to the shelter cost. The final column in Table 3.4 shows unit costs that would be reasonable to use in planning a shelter incentive program, considering the general nature of slantable construction described in Section II.

It is often desirable to express shelter costs as a percentage of the overall cost of constructing a building. Typical results are shown in Tables 3.5 and 3.6. It will be noted that all-effects shelter generally runs less than 5 percent of total building cost. Exceptions are commercial buildings and multi-family housing. The relatively high cost in commercial property is the result of two factors: (1) low unit cost of construction, and (2) the need to provide shelter for both employees and customers. The somewhat higher cost in multifamily housing is because of the low unit cost of construction.

TABLE 3.4

SHELTER COST SUMMARY

(1983 Dollars)

Shelter Type	Estimated Cost Range ($ per sq. ft.)	Recommended Planning Value ($ per sq. ft.)
PF 40 Fallout	3.00 - 4.65	4.00
PF 100 Fallout	3.81 - 5.95	5.00
15-psi All-Effects	17.12 - 33.24	20.00
20-psi All-Effects	18.74 - 22.67	22.00
30-psi All-Effects	23.09 - 27.72	27.00
Earth Berms	1.80 - 14.20	6.00

TABLE 3.5

ALL-EFFECTS SHELTER COSTS AS PERCENT OF PROJECT COST

BUILDING CATEGORY	AVERAGE PROJECT COST (000 $)	AVERAGE FLOOR AREA (sq. ft.)	ASSUMED OCCUPANCY (sq. ft. per person)	PERCENT OF PROJECT COST* 15 psi	20 psi	30 psi
Office Buildings	744	10,270	100	2.4- 4.6	2.6- 3.1	3.2- 3.8
Commercial	253	6,690	60	7.5-14.6	8.2-10.0	10.1-12.2
Manufacturing	398	7,360	100	3.2- 6.2	3.5- 4.2	4.3- 5.2
Educational	582	6,910	80	2.5- 4.9	2.8- 3.4	3.4- 4.1
Hospitals & Health	1,686	15,880	190	2.1- 4.1	2.3- 2.8	2.9- 3.5
Other Nonresidential	336	4,490	100	2.3- 4.4	2.5- 3.0	3.1- 3.7
TOTAL NONRESIDENTIAL	470	7,590	81	3.7- 7.0	4.0- 4.8	4.9- 5.9
One-Family Developments	4,891	123,750	650	0.6- 1.3	0.7- 0.9	0.9- 1.1
Multi-Family Housing	486	12,700	100	4.5- 8.7	4.9- 5.9	6.0- 7.2
Nonhousekeeping Residential	1,275	18,340	100	2.5- 4.8	2.7- 3.3	3.3- 4.0
TOTAL RESIDENTIAL	1,282	31,790	225	1.9- 3.7	2.1- 2.5	2.5- 3.1
ALL BUILDINGS	737	15,650	143	2.5- 4.9	2.8- 3.4	3.4- 4.1

*Based on data in Tables 2.7 and 3.4, assuming shelter is provided for building occupants at 10 square feet per person.

TABLE 3.6

FALLOUT SHELTER COSTS AS PERCENT OF PROJECT COST

BUILDING CATEGORY	AVERAGE PROJECT COST (000 $)	AVERAGE FLOOR AREA (Sq. Ft.)	ASSUMED OCCUPANCY (Sq. Ft. Per Person)	PERCENT OF PROJECT COST* PF 40	PF 100
Office Buildings	350	4,870	100	0.4-0.7	0.5-0.9
Commercial	119	3,170	60	1.3-2.1	1.7-2.7
Manufacturing	187	3,460	100	0.8-1.3	1.0-1.6
Educational	276	3,160	80	0.5-0.9	0.7-1.1
Hospitals & Health	797	7,370	190	0.4-0.6	0.5-0.7
Other Nonresidential	158	2,200	100	0.9-1.5	1.2-1.9
TOTAL NONRESIDENTIAL	219	3,590	81	0.7-1.1	0.9-1.4
One-Family Developments	2,302	57,270	650	0.1-0.2	0.1-0.2
Multi Family Housing	229	5,970	100	0.8-1.2	1.0-1.6
Nonhousekeeping Residential	600	8,330	100	0.4-0.7	0.5-0.8
TOTAL RESIDENTIAL	604	14,780	223	0.3-0.5	0.4-0.7
ALL BUILDINGS	347	7,310	142	0.4-0.7	0.6-0.9

*Based on data in Tables 2.8 and 3.4, assuming shelter for 50 persons or occupants, whichever is larger, at 10 square feet per person.

3.9 Home Shelters

Although the main thrust of this study is toward programs to incorporate public shelter space in new construction, it may be seen desirable to provide incentives for the incorporation of appropriate protection in individual homes. As shown in Table 2.4, nearly a million one-family houses will be built in an average year. Only two-thirds of these have been included in the category of "One-Family Developments" in Tables 3.5 and 3.6. By excluding individually built residences, the potential for about a million shelter spaces yearly is lost, assuming an average household size of about 3 persons. Moreover, buildings with less than 5 housing units have been excluded from the category, "Multi-Family Housing." These residences could be served by home-type shelters.

A major source of data on fallout protection in new residential structures can be found in a report prepared in 1969 by the National Association of Home Builders Research Foundation.[14] This report provided design details, specifications, and costs for 16 alternative shelter designs having a PF of 40 for inclusion in the construction of new homes. The additional cost of these shelters, updated to 1983, ranged from $4 to $14.70 per square foot of shelter space. The higher costs were associated with designs for houses without basements. Improving the protection to PF 100 would increase these costs by about 25 percent, or to a range of $5 to $18 per square foot. Thus, a 5-person home fallout shelter (50 square feet) could be included in a new home for $250 to $900.

Shelter also can be provided for the occupants of both new and existing homes by burying a shelter completely belowground adjacent to the residence. Examples of such shelters can be found in FEMA publications[15,16] that describe a PF-40 fallout shelter and a 15-psi blast shelter, each accommodating 6 people. Construction cost data for these designs is not available. Our estimate is that the fallout shelter would cost about $6,000 ($100 per square foot) and the blast shelter $10,000 ($167 per square foot). Larger shelters for 10 to 20 persons have been designed that protect against 30 to 50-psi blast overpressure at an estimated cost of $65 to $105 per square foot.[17]

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SECTION IV
ANALYSIS OF INCENTIVE OPTIONS

4.1 Introduction

In the present context, incentives are offered to owners of proposed new structures in an attempt to induce them to include public shelter space in the projects when they are built. Owners differ in their roles in society and in the nature of their ordinary activities and thus may be expected to have different purposes and objectives in building the new structures, some (e.g., governments) to obtain places in which to conduct their normal activities, others to sell or rent them for profit. It is also to be expected, then, that different owners will respond favorably to different kinds of incentives. In addition, while some of the available incentives might be appropriate for all classes of owners, others would simply not apply to some of them.

4.2 Classes of Ownership

For the discussion of incentives, owners can be classified on two bases: (1) the purpose for which the proposed structure is to be built and (2) the liability of the owner to pay taxes to the Federal government. Six classes of owners can be identified for this purpose:

- Federal Government: all agencies of the Federal government.
- State and Local Government: all agencies of State and local government except as owners of primary and secondary schools; hospitals, clinics, and nursing homes; and recreational facilities.
- Health and Welfare Institutions: government and private owners of primary and secondary schools; government owners of hospitals, clinics, nursing homes, and recreational facilities; and all nonprofit institutions exempted from Federal taxation under Sections 501(c) and 170(c) of the U.S. Internal Revenue Code (26 U.S.C. 501(c) and 170(c)).
- Other Nonprofit Institutions: fraternal and other institutions listed in Section 501(c) but not qualifying for exemption under Section 170(c) of the U.S. Internal Revenue Code.
- Residential Property Entrepreneurs: owners of facilities to be built for use as housing: including homes, apartment buildings, hotels and motels.
- Industrial Entrepreneurs: owners of facilities to be built for use in industry and commerce.

Table 2.12 shows that the latter two ownership classes, which constitute the private for-profit sector, dominate the construction scene. They are responsible for about two-thirds of the buildings to be built and, if one-family developments are included, about three-quarters of the valuation of new construction. Thus, incentives to include multi-hazard shelter certainly must appeal to private entrepreneurs if a shelter incentive program is to be successful.

J. B. Wellisch et al[1] analyzed the nature and role of building owners in the slanting of new construction for fallout shelter in 1970. They found sharp differences between public owners and private owners in their attitudes and characteristics. The two groups were similar in their awareness of the Government's fallout shelter program: 81 percent of public owners and 71 percent of private owners were aware. But, over half the public sector officials interviewed had some knowledge of fallout protection as compared with less than one-quarter of the private sector respondents. To quote the research findings,

> "In the dimensions of attitude and level of knowledge, there appear to be significant differences between the sectors with the private sector scoring fairly low in both dimensions. This is somewhat surprising, since it will be remembered that no interview could be arranged with more than half the private cases contacted, which led us to expect that the interviews that were granted were with the less negative and more knowledgeable of the privates. This could imply that differences between the two are so extreme that screening tended to minimize but not erase these differences. Also, the fact that negative responses to our requests for interviews came solely from the private sector, is in itself a startling bit of evidence that the public and private populations are basically different."

At the time of the interviews, building construction costs were increasing at a rate of 1 percent *per month*. This inflationary situation, coupled with difficulties in getting approval of bond issues in the public sector, made both groups extremely sensitive to additional costs attributable to fallout shelter.

> "*Cost* as a reason for nonparticipation did not discriminate private from public cases, nor did it discriminate those with negative attitudes toward fallout protection from those with positive attitudes. Even individuals who evidenced a high degree of personal commitment, as well as those who represented organizations that had a policy to incorporate fallout protection where feasible, gave additional costs as a prohibiting factor."[1]

Fear of inflation also made delay a critical issue in dealing with the Government. Often referred to as "red tape", there was some indication that worries about possible delays in the construction schedule would have discouraged many from participating in a shelter slanting scheme even if cost was not an issue.

4.3 Kinds of Incentives

Several different incentives are appropriate for a program that involves action by the owner to include shelter in a new building or project. These incentives are generally of two kinds: (a) those that impose a penalty if the owner does not participate and (b) those that offer a benefit if the owner does participate.

Two of the incentives impose a penalty:

- Legal Mandate is the requirement by Federal law that shelter be included in all newly-constructed buildings (or projects not exempted) with penalties for failure to comply.

- Program Qualification is a denial of the opportunity to participate in any program in which the Federal government provides financial assistance to the owner if the owner fails to incorporate shelter.

Three of the incentives offer a benefit:

- Direct Payment is a payment of funds by the Federal government either directly or through low-interest loans.

- Indirect Payment is a forgoing of the collection by the Federal government of some or all of the tax payment the owner would otherwise make.

- Technical Assistance is the supplying to the owner by the Federal government, without charge, of technical information to assist in incorporation of shelter, reduction in its cost, or both.

4.4 Legal Mandate

Without doubt, the most effective incentive could be the enactment of a public law requiring all owners to incorporate shelter in new construction and establishing penalties for non-compliance. Versions of this approach have been tried in several States in this country and other versions are common in several European countries as described in Section I.

However, it might not be appropriate to require every owner to incorporate shelter in every new building. As discussed in Section 2.12, requiring the inclusion of shelter in small projects would introduce inefficiency in program management. And, i. _ minimum shelter capacity (e.g., 50 spaces) is wanted, requiring shelter in small projects would be inequitable because the relative cost of adding shelter in them would be high when compared to that for larger projects. In addition, many projects would not be suitable for inclusion of shelter because the normal use of the building is hazardous of itself. As a result of such considerations, a legal mandate requiring the incorporating of shelter would have to provide for exemptions. These exemptions would have to be limited because to allow exemption for trivial reasons could well defeat the program.

Adoption of the legal mandate would not necessarily exclude other incentives. For example, to require shelter in all buildings not exempted need not preclude financial assistance to some classes of owners. In the past, objections have been raised to requiring shelter in school buildings to be paid for out of school construction appropriations because, it was held, the appropriations were intended to provide education, not protection. And while such objections may not be completely valid, they could erode public support for the program and lessen the probability of its adoption. Therefore, the legal mandate incentive could be accompanied by, say, direct payment for shelter in schools.

The legal mandate incentive need not necessarily apply to all classes of owners. For example, incorporation of shelter could be legally mandated in government-owned buildings but voluntary for private owners with other incentives being offered. Or the legal mandate could be made to apply only to the Federal government and other incentives offered to State and local governments as well as private owners. However, unless the legal mandate is made to apply to the Federal government as an owner, the prospect for voluntary participation by other owners would not likely be bright.

In summary, then, the legal-mandate incentive can be made to apply to some or all classes of owners either as the only incentive or in combination with one or more of the other options. It is the only incentive appropriate to the incorporation of multi-hazard shelter in Federal buildings. Many would argue that mandatory shelter in Federal buildings is an essential ingredient in any broader shelter incentive program.

4.5 Program Qualification

Program qualification would provide an incentive by requiring the owner of new construction to incorporate shelter into a project in order to qualify for federal financial assistance. In theory, denial of participation could extend to any federal program whether related to construction or not. But this would seem to be undesirable because such a widespread intrusion would necessitate overly complicated administrative arrangements. Therefore, the program qualification incentive would best be applied to those other programs in which the Federal government offers assistance for construction.

Federal programs to support new building construction are limited to housing, which can be seen in Tables 2.7 and 2.8 to constitute about 40 percent of the potential number of new shelter spaces the incentive program might achieve. Direct payments and loans are available only to nonprofit sponsors and State and local governments; FHA and VA insurance are available to private individuals. Currently active federal programs that could be involved in a program qualification incentive for slanted construction include the following:

- FHA Mortgage Insurance: The Federal Housing Administration provides insurance on mortgages for single and multi-family housing, mobile homes, and health care facilities. This insurance protects lenders from loss in the event of default on the loans and may thereby enable borrowers to obtain loans that might otherwise not be available or to obtain better terms than are available in its absence.
- Housing for the Elderly and Handicapped (Section 202): HUD provides direct loans to finance the construction of rental housing for the elderly and handicapped.
- Public and Indian Housing: HUD makes direct loans or annual contributions to Public and Indian Housing authorities for debt services in the private sector.
- Rental Housing Development Grant (Section 17): HUD provides assistance to States and local governments to enable development of rental housing.

The proposed FY 1986 budget includes a two-year moratorium on new commitments for the Elderly and Handicapped and Public and Indian Housing programs and proposes no new commitments for new construction in the Rental Housing

Development Grant programs. In general, the number of federal programs related to new construction has been reduced by eliminating programs or by changing the emphasis to support of existing housing rather than new construction. Statutory authority for such programs remain and new construction could be reemphasized in the future. The dollar amount of activity in housing programs in 1983 is shown in Table 4.1.

How effective the program qualification incentive might be would depend largely on how the potential participants in these housing projects would react to the requirement. Incorporation of shelter would increase the cost of a project and this could cause some developers to forego the project thus failing to produce both shelter and housing. This adverse effect could be reduced if payment incentives were offered to cover the cost of adding shelter especially if they were made at the outset to eliminate the impact on long-term financing costs.

4.6 Payment Incentives

The obvious purpose of payment incentives is to induce owners voluntarily to incorporate shelter space in their newly-constructed projects. It would seem, then, that the legal mandate incentive would obviate payment incentives. But this is not necessarily so. Requiring owners either to absorb the cost of adding shelter or to pass it through to consumers could place some people, owners or consumers, at an economic disadvantage compared to those who own, occupy, or purchase goods or services produced in facilities built before the shelter incentive program. Inclusion of payment incentives in combination with a legal mandate incentive would serve to reduce such inequities.

On the other hand, if the public were to become convinced of the need for shelter, facilities with shelter would be more desirable than those without it. In that case, consumers might well be amenable to higher prices and the need for payment incentives would tend to disappear.

In the payment incentives (direct or indirect), the Federal government would bear some or all of the cost of incorporating shelter in new construction. Whether the government should pay all of the cost or only part of it is a matter of choice in program design. In the absence of the legal-mandate incentive, it seems likely that more shelter spaces would be achieved when the Federal government absorbs all of the added cost or even pays a premium

TABLE 4.1

HOUSING PROGRAM ACTIVITY - 1983

Program	Activity ($)
Public and Indian Housing	
New Direct Loans	247,295,000
Guaranteed Loans	14,260,636,000
(New commitments)	
Housing for Elderly and Handicapped	
Direct Loans	633,338,000
(Obligations incurred)	
Federal Credit Agencies	
New Multifamily Housing (1)	2,700,000,000
(Loans originated)	

Sources:

1. Statistical Abstract, 1985
2. All other: Appendix to 1985 Budget

than when it pays only a part of it. But whether the government is to absorb part or all of the cost, it is necessary to determine on what cost the payment is to be based.

The "cost" of adding shelter can be arrived at in two ways. In one, alternative designs for the proposed project can be made (one without shelter, the other with it) and the cost of each estimated. The difference between the estimates can then be ascribed to the incorporation of shelter. In the other, a flat-rate allowance for shelter space can be established and the added cost of shelter can be taken to be equal to the rate times the number of shelter spaces to be created. Both methods have been proposed in past program designs.

The rationale for the two-design method has been that it eliminated the possibility of the owner's making a profit on the incorporation of shelter. But this is not necessarily so. Cost estimators are ingenious and it would require detailed analysis of the two estimates to assure that the difference between them truly reflected the cost of adding shelter. In addition, the cost of making the alternative designs and cost estimates are logically attributable to the adding of shelter and of themselves serve to increase its cost. On the other hand, the use of the flat-rate is simple; it requires only a determination of the number of shalter spaces to be achieved, thus eliminating both the added cost of the alternative designs and the administrative cost of reviewing them.

In addition, the "no-profit" rationale seems to contain several fallacies. In the first place, production of other elements of national defense is not performed "at cost." Those who build guns and ships and tanks are allowed a profit. Besides, development of new techniques and methods of slanting new construction to obtain shelter and a resulting reduction in slanting costs can be expected as a by-product of the efforts of owners (and their architects and engineers) to incorporate shelter at less cost (to the owner) than the flat-rate allowance.

It appears, then, that more shelter would be produced for a given program cost when payments (direct or indirect) are based on a flat rate per shelter space, giving due recognition, of course, to the difference in cost between all-effects shelter and fallout shelter.

In the direct payment incentive, the Federal government would provide funds to the owner to defray the cost of adding shelter. In the indirect payment incentive, the government would forego collection of taxes owed by the owner in an amount equivalent to a direct payment. Thus, the indirect payment incentive would be available only to owners who have a federal tax liability while the direct payment incentive could be made available to all owners.

In the case of tax-paying owners, the choice between direct and indirect payment incentives is a matter of program design. And while it may seem that it makes little difference which is chosen, that is really not so. It costs money to collect taxes and to make payments and the gross cost of obtaining shelter spaces through indirect payment incentives should be less than through direct payment. On the other hand, serious objections have been raised to use of taxation for purposes other than raising revenue and critics often point to the difficulty in identifying the real cost of a program when payments are made in the form of tax offsets.

4.7 Direct Payment

In the direct payment incentive, the Federal government would pay out funds -- actually or in effect -- to the owner for the incorporation of shelter in new construction. This payment could take several forms:

- Grant. In this form the Government would pay to the owner the amount of money established by the terms of the program for the type of shelter (all effects, fallout) and the number of spaces incorporated in the project.
- Low-interest Loan. In this form the Government would lend the money directly to the owner to finance the new construction at an interest rate below the market. In effect, a grant is provided equivalent to the present value of the difference between the amount of interest the borrower is scheduled to pay and that which he would have had to pay at the market rate over the life of the loan.
- Loan Subsidy. In this form, a commercial lender would make the loan at the below-market interest rate and the Government would

reimburse the lender for the present value of the difference between the amount of interest the borrower is scheduled to pay and that which would be paid at the market rate. In housing programs this has been done through the Government National Mortgage Association (GNMA), who buys the loan from the commercial lender and sells it at a discount in the secondary market.

While all three forms of payment could be made available to all owners, grants and low-interest loans have been made only to state and local governments and to nonprofit sponsors. Loan subsidies can be made available to any owner who requires financing in the commercial market.

Direct payment is the only payment incentive appropriate for offering to owners who have no federal income tax liability: Federal, State, and local governments and selected health, welfare, and other non-profit institutions (see Paragraph 4.2). Owners who have federal income tax liability could be offered either direct or indirect payment incentives. They, of course, are responsible for up to three-quarters of all construction.

While there may seem to be no point in making direct payments for incorporation of shelter in Federal buildings, the realities of appropriation procedures of the Congress may render it necessary. This would occur when one committee passed on the appropriation for shelter and another on the appropriation for the project in which the shelter was to be incorporated. In that case, it might be advisable to appropriate funds for slanting and provide means for inter-departmental transfer of funds to supplement the funding of the new project.

The Civil Defense Act of 1950 (50 USC App. 2251-2297) established civil defense to be the joint responsibility of the Federal, State, and local governments. Over the years, this division of responsibility has appeared several ways. The cost of some program elements (e.g., supply of radiation instruments and NCP planning) has been borne entirely by the Federal government. The cost of others (e.g., construction of emergency control centers and program management) has been equally divided between the Federal government and the States. Therefore, the precedent exists for direct federal payments to the States for civil defense purposes.

The fraction (if any) of the cost of adding shelter to new State and local facilities to be paid by the Federal government is a matter of program design. It seems reasonable to expect that, so long as incorporation of shelter is voluntary, the larger the fraction of its cost borne by the Federal government, the more likely it is that shelter will be incorporated. On the other hand, when slanting is mandated by Federal law, full compliance may be expected. But the future of Federal grants and payments to the States is uncertain at this time. And while this is not the place for a discussion of Federal grants, it does seem logical that the Federal government ought to be prepared to pay for whatever it demands.

Direct federal payments are the only incentive available for Health and Welfare and Other Nonprofit institutions absent the legal mandate incentive. Even with the legal mandate, direct payments to Health and Welfare owners would be appropriate. These institutions provide services seen to be important to the public good and all of the funds available to them, whether from taxes or from charitable contributions would best be devoted to their original intended purposes. Whether direct payments to other nonprofit institutions in addition to the legal mandate would also be appropriate is not as clear. However, in the absence of a legal mandate, direct payments to Health, Welfare, and Other Nonprofit institutions for the incorporation of shelter seems necessary if a substantial participation in the program by such institutions is to be achieved.

4.8 Loan Subsidies

It can be seen in Table 2.12 that about two-thirds of the potential projects (Private For-Profit) could be eligible for loan subsidies if this form of direct payment were included in the program. One precedent for such an incentive is found in the Solar Energy Bank in which the subsidy is paid on that portion of the loan attributable to the cost of buying and installing solar energy equipment. In that program, payment is made to the lender on origination of the loan. The program is administered by GNMA who testified that few additional employees would be required for its administration.

Another precedent is found in Section 235 and 236 housing programs in which interest rate subsidies are intended to encourage builders to construct lower income housing. These subsidies were combined with loan guarantees to encourage lenders to participate. Payments were made to the lending institutions equal to the difference in monthly installments between amortization at the FHA ceiling rate and that calculated at one percent interest. According to HUD,[2]

> "This mechanism (Section 236) proved to be quite successful in encouraging developer participation resulting in very high levels of program activity. Overall Section 236 produced more multifamily housing units in only a few years than any other multifamily insurance program and more total units than every other subsidy program except public housing."

On the other hand, the Section 236 program has been criticized for having a costly combination of subsidies and for the high default rate which has been attributed to the loan guarantee provision.

It appears that the Solar Energy Bank would be a suitable model for a loan subsidy program for a shelter incentive. In it the subsidy is related to the cost of installing the solar equipment. In the shelter incentive program, the subsidy could be related to the cost of incorporating shelter or to a flat-rate allowance depending on the design of the program.

4.9 Indirect Payment

In the indirect payment incentive, the Federal government would allow an owner who incorporates shelter in new construction to reduce the amount of his liability for federal income tax. Two principal methods are used for determining the amount of the reduction:

- Tax Credits. A tax credit is a direct offset against the income tax liability: dollar for dollar. It can be made to apply to the current year's liability and if it exceeds that amount, it can be made to carry back to previous years or forward to subsequent years. The amount of the offset is independent of the taxpayer's marginal tax rate.

- Tax Deduction. A tax deduction is an offset against the income on which income tax is levied thus reducing the amount of the tax liability. The amount of the reduction in tax liability for a given amount of deduction depends on the taxpayer's marginal rate. Several forms of deductions have been employed in programs that may be comparable to the shelter incentive program.

The mechanism for administering a tax incentive option exists through the normal procedures of the Internal Revenue Service. The primary concern of the IRS would be the auditability of the credit or deduction. This could be achieved through a field certification program by qualified shelter analysts which would likely be a requirement for any incentive option. The certificate could be submitted along with a simple form to claim the deduction or credit. The deduction or credit would be handled by the IRS as any other tax incentive. The IRS role in auditing the incentive could be limited to verifying the authenticity of the certificate if the incentive were structured on a performance basis. If it were structured on a cost basis, the IRS would have to determine that the costs were substantiated as well. The indirect payment incentive approach should not significantly increase the IRS workload.

4.10 Tax Credits

Numerous tax credits are currently allowed by the tax code, thus establishing a substantial precedent for a tax-credit incentive for incorporation of shelter. Notable currently are the provisions of credit for investment in a variety of property; e.g., machinery, equipment, reforestation, energy conservation, agricultural properties for production of food and fiber, and in rehabilitation of older and historic buildings. The amount of credit varies. For qualifying rehabilitation projects, the credit is equal to 25 percent of the cost of rehabilitating certified historic structures, 20 percent for 40-year-old buildings, and 15 percent for 30-year-old buildings. For investments in other qualifying property, the credit is equal to 10 percent of 60 percent of the cost of 3-year property and of 100 percent of the cost of 5-year (or more) property. The amount of the credit is limited to the first $25,000 of tax liability and 85 percent of the liability exceeding $25,000. Currently, the investment tax credit does not apply to real property. Use of tax credits in some recent years is shown in Table 4.2.

There is precedent for a flat-rate/unit type of tax credit. Fuel production from non-conventional sources earns a credit of $3 per 5.8 million BTUs produced and sold. In addition, a credit of 50 cents per gallon is earned for use of alcohol as fuel. However, adoption of a flat-rate/unit tax credit as a shelter incentive would require the addition of a new provision to the tax code rather than a modification of an existing provision.

Builders/developers appear to have a clear preference for tax credits as opposed to other forms of tax incentives. In a survey of the opinions of

TABLE 4.2

USE OF INVESTMENT TAX CREDIT
BY INDIVIDUALS AND CORPORATIONS*

	Individual			Corporation		
Year	No. of Tax Returns with Credit (Millions)	Investment Credit Total ($Billion)	Income Tax (after Credit) ($Billion)	No. of Tax Returns with Credit (Millions)	Investment Credit Total ($Billion)	Income Tax (after Credit) ($Billion)
1978	3.9	2.9	186.7	2.4	12.9	107.9
1979	4.2	3.3	213.3	2.6	14.6	120.0
1980	4.2	3.3	249.1	2.7	15.1	105.1
1981	4.5	4.0	282.3	2.8	18.9	102.3
1982	4.4	4.1	277.6	--	--	--

*Data extracted from "Individual Income Tax Returns" IRS, for years 1978-1982 and "Corporation Returns" IRS for years 1978-1981.

investors with respect to tax law provisions affecting multi-family housing, it was found that tax credit was the best change to make during the construction period to make apartment investments more attractive.[3] Testifying before Congress, Mr. Peterson of the National Association of Home Builders said that the tax credit approach to encouraging construction "is the most preferable incentive to builders across the country." Credits appear preferable to deductions because,

- they are a more direct type of incentive: easier to understand and to compute,
- they provide a greater sense of liquidity because the invested capital is returned more quickly, and
- they treat all taxpayers equally regardless of tax bracket and relate the benefit directly to the amount invested.

Evidence found in Congressional hearings on incentives for various purposes indicates that the tax credit approach is preferred over other types of incentives such as direct payments and subsidies. In the opinion of Rep. Ullman, tax credits are preferred because they have wider application and minimize red tape.[4] This does not mean that the Congress does not have reservations. Rep. Frenzel expressed his concern that an incentive might give someone a prize for doing something he would do anyway.[4]

4.11 <u>Amount and Structure of Tax Credits</u>

It is almost axiomatic that tax credits affect economic behavior. However, the credit must be sufficiently large in order to be effective in motivating large numbers of developers to participate in whatever a program is trying to achieve. For example, it has been concluded that the 10 percent Energy Investment Tax Credit has had no impact on industry decisions to invest in energy efficiency.[5] According to Dr. Roberg (OTA) in his testimony, the 10 percent credit was

> "... too small to exert any change on the returns of investment of most projects or on the cash flow of the company. A firm has an overall objective of increasing productivity and therefore profitability when making an investment.... Energy is just one of the many factors determining productivity of a given process, and a targeted incentive, such as the EITC, is diluted to the degree energy efficiency must compete with other factors for investment priorities."

It was judged that the EITC would have to be increased to 40 percent to be effective.

The situation with respect to a tax credit for incorporation of shelter is somewhat analogous to the EITC in that targeted shelter credit would be only one of many factors influencing the decision of the developer on building design to achieve a profitable investment. In fact, the shelter situation is more difficult because slanting to create shelter, unlike an investment in energy efficiency does not in and of itself yield a return on investment. At present there is not a perceived market for protected spaces that would enable a developer to pass on the higher cost of slanted construction to buyers or renters and thereby obtain a return on the investment in slanting. Unless and until such a market were to develop, the tax credit would be the sole source of a return on the investment in slanted construction. Therefore, the tax credit to be effective must be sufficiently large not only to reimburse the developer for the incremental cost of slanting but also to provide the developer with a return on the incremental investment sufficient to motivate him to make the additional investment.

In the main, shelter would be incorporated by slanting the construction of below-ground spaces. Thus the costs of slanting would be incurred early rather than late in the construction period. If the enabling legislation were to allow credit to be claimed in the year the building is placed in service, there would be a lag of about one year between the incurring of cost and the realization of cash flow from the tax credit. The delay could be shorter if the developer had a current tax liability and realized a cash flow through reduction in estimated tax payments. It could be much longer if the credit were carried over to subsequent years.

The effectiveness of the tax credit would be reduced if the enabling legislation required a reduction in the basis for depreciation in proportion to the slanting credit. If such a requirement were not imposed, the developer would then receive the same tax savings from the slanting portion of the cost as on the rest of the building.

It appears, then, that in order for the tax credit incentive to be effective, it should be equivalent to the added cost of construction plus an amount sufficient to provide a sufficient return on the developer's investment in the shelter construction for the period between the incurring of the cost and the realization of the credit.

4.12 Tax Deductions

Two forms of tax deductions are of interest in the context of a shelter incentive:

- Accelerated Cost Recovery (ACRS). In this the annual depreciation allowance is increased by shortening the recovery period.

- Construction Period Expense. In this the interest on the investment and the state and local taxes incurred during the construction period would be allowed as necessary business expense.

In both types, the benefit available to the taxpayer depends on his marginal tax rate.

A shelter incentive of the ACRS form could be adopted by a modification of the current ACRS provisions in the tax code. It would require development of an alternative deduction schedule based on a shorter recovery period for qualifying property similar to the treatment of low-income housing which currently has a 15-year recovery period in contrast to 18 years for other real property. It would also require that qualified non-residential property be treated in the same manner as residential for recapture of ACRS allowances. Currently residential ACRS allowances in excess of straight-line recovery are recaptured as ordinary income while all ACRS allowances for non-residential property are recaptured.

The situation with respect to ACRS as an incentive for incorporation of shelter is somewhat different from that for housing. There is a market for housing and the ACRS tends to expand the market by reducing the cost to the consumer thus making the developer's investment appear more desirable. However, there is no current market for shelter. As in the case of tax credits, ACRS would be the sole source of a return on the investment in slanting. Therefore, the ACRS would have not only to reimburse the developer for his investment in slanting but also provide him a return on that investment sufficient to motivate him.

In the case of the tax credit, the delay between investment in slanting and the realization of cash flow from the tax credit would be on the order of one year. In the case of ACRS, it would take 15 or more years for the developer to recover his investment and it would be necessary to provide him a return on the declining balance over all that period. Thus, ACRS would be far more complex to compute and apply than a tax credit and it could well be far more expensive. This problem, together with the dependance of the ACRS benefit on the developer's tax bracket, appears to render a tax-credit incentive far preferable to ACRS.

Currently, construction period interest and taxes must be amortized over a 10-year period except for low-income housing and property not held for business or investment. Prior to 1981, these costs were treated as expense and deducted from income in the year in which they were incurred. As a shelter incentive, qualifying projects could be excepted from the amortization requirement. Here again, the tax credit would appear to be far preferable because expensing of interest and taxes might not reimburse the developer for his investment in shelter, let alone provide him a return on his investment.

4.13 Technical Assistance Incentive

The providing of technical assistance in the methods of design and construction for slanting of structures to provide shelter is a necessary incentive. Uncertainty is a disincentive. Developers are not normally inclined to invest in projects with which they are not familiar and which may not reasonably be expected to produce a desirable return on their investment. Architects and engineers are not normally inclined to take on design projects that are not within their perceived areas of competence. Few developers have had "hands on" experience in building projects that intentionally incorporated shelter. And while a substantial number of architects and engineers have had some training in analyzing structures to ascertain their shelter capability, an ability to analyze is not the equivalent of an ability to create a design that will be efficient and economical.

To provide technical assistance, then, would serve to reduce the uncertainty and enhance the effectiveness of whatever other incentives were offered. That this is so is demonstrated in Paragraph 1.13 which recounts that some owners who received technical assistance incorporated shelter in their new buildings with no other incentive.

In addition, the process of technical assistance (described in Section V) provides a means of acquiring information on the improvements in the state of the art of slanting new construction that are inevitable when architects and engineers apply their ingenuity and resourcefulness to the problems encountered in designing buildings in real situations. It also provides a means of introducing the new ideas quickly with the likely results of enhancing participation in the program and lowering the eventual program cost.

4.14 Applicability of Incentives

As noted earlier on, the applicability of some incentives is limited; i.e., they are not appropriate for offering to all classes of owners. This is shown in Figure 4.1 where it can be seen, for example, that the legal mandate could apply to all classes of owners but the tax credit incentive could apply only to industrial owners. It is noted that while grants and low-interest loans could be offered to industrial owners, it has not been the practice to do that. Similarly, loan subsidies could be offered to State and local governments but it has been the practice to subsidize them through grants and low-interest loans.

4.15 Slanting Benefits and Penalties

Aside from the various types of program incentives noted and discussed in this Section, there are some additional design benefits to be derived from incorporating shelter in new structures. The rapid rise in the price of oil in the late 1970s caused building designers to focus their attention on energy conservation design techniques to improve building thermal efficiency, thus reducing consumption of energy. Studies made by the Defense Civil Preparedness Agency [7,8] showed that shelter design and energy conservation features may be considered as two of the many requirements in the building design process and that architects and engineers can deal with both problems simultaneously. Many of the architectural design techniques that provide protective shelter in a building also contribute to energy conservation. For example, the size and location of openings in a building will have a direct influence on a building's shielding characteristics as well as its thermal efficiency. The same can be said about selection of materials for their thermal properties. Walls and roofs of heavier mass thicknesses, which are designed for shelter purposes, have lower peak thermal transmission values than do lighter-weight enclosures.

TYPE OF INCENTIVE		CLASS OF OWNER: Government — Federal	Government — State	Government — Local	Non-profit Institutions	Entrepreneurs
Legal Mandate		●	●	●	●	●
Program Qualifications			●	●	●	●
Direct Payment	Grant		●	●	●	
Direct Payment	Low Interest Loan		●	●	●	
Direct Payment	Loan Subsidy				●	●
Indirect Payment	Tax Credit					●
Indirect Payment	Accelerated Cost Recovery					●
Indirect Payment	Interest and Tax Expensing					●
Technical Assistance		●	●	●	●	●

Figure 4.1: Applicability of Incentive

The design technique for placing a building (or a portion of a building) completely or partially below ground not only improves its shelter potential, but also improves its thermal characteristics and provides for more energy conservation. In addition, increased attention is being given to below ground construction, especially in urban areas, because of: (1) a shortage of space in prime development areas; (2) continually rising costs of real estate; (3) a reduction in excavation costs due to advancements in technology; and (4) an increased sensitivity to the plight of displaced persons and the historical value of buildings that have to be demolished to make way for new construction.

Increased safety from tornadoes and high winds is another design benefit from underground construction. Many school districts have taken actions to construct their schools with portions completely below ground so as to provide tornado shelters for students and teachers.[9] These belowgrade areas also provided fallout protection and could have been designed as all-effects shelters if this had been a design criterion.

Other design benefits from underground construction include: increased protection from noise pollution;[10] improved earthquake protection since subsurface facilities are subject to little or no structural shear during an earthquake; lower maintenance and operating costs since there is less wear and tear brought on by extremes of weather; and a potential reduction in vandalism since windows, which are the frequent targets of vandals, are nonexistent.

While there are a number of design benefits to incorporating shelter in building designs, it should also be noted that some changes in the design to accommodate the shelter requirements may be detrimental to the normal daily use and function of the shelter space. This is more so for all-effects shelters than those providing only fallout protection. For example, all-effects shelters require that openings into the basement shelter area be "sealed off" to prevent the blast overpressure from entering as well as shielding out the INR. Design modifications such as providing blast doors, ventilation closures, entryway offsets, baffle walls, and relocating or shielding of elevator, stairwell, or escalator openings would be required to attain all-effects shelter protection. Some of these design modifications may interfere with the daily use of the shelter space and, therefore, might be considered as a penalty or a "disincentive" by the building owner or designer. Another disincentive may be the increased time required for the design and construction of an all-effects shelter as opposed to a non-protected facility. When building owners are faced with increased costs, they may be reluctant to participate. Participation is more likely to be forthcoming if there is a perception that the shelter incentives and design benefits will more than offset the penalties involved and that an overall financial benefit will be available to the building owner if an underground shelter is constructed.

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SECTION V

PROGRAM MANAGEMENT ALTERNATIVES

5.1 Basic Program Needs

Irrespective of the program alternative that is finally selected, FEMA program managers will need specific information and special resources available to them to effectively implement and manage the Shelter Incentive Program (SIP). In addition to the basic management technique for establishing a system that will enable the program manager to measure effectiveness of the new program to incorporate shelter in new designs, the following activities are also considered to be essential for the success of a Shelter Incentive Program:

(a) A system that provides data on new design and construction projects (e.g., project size, type, location, estimated construction cost, etc.) for project identification and tracking purposes. The system should permit contact with the project owner and designer to advise them of the shelter incentive program and encourage (or mandate) them to include protective shelter in the design of their new structure.

(b) A capability and means for providing technical guidance and assistance to project designers so that they can effectively incorporate protective features in newly designed projects early in the design phase when it is most economical to do so.

(c) A cadre of trained shelter analysts who will be able to assess the quantity and level of shelter protection provided in designs of new structures and certify that such shelters were included.

5.2 Data on Individual Projects

Information on new design projects is available from commercial sources. The best known and most widely used source is the F. W. Dodge Division of McGraw Hill Information Systems Co., New York, N.Y. The F. W. Dodge Co. has news gatherers in strategic locations throughout the country where they maintain contact with the designers, planners, builders and others involved in new design and construction projects. They maintain a data bank of information on each new project that includes ongoing, detailed information on what is happening and what will happen throughout the life of the project - from its inception until construction is completed and occupancy accomplished. Dodge Reports are available for all States except Hawaii. Other reporting services will be required if nationwide coverage is to be achieved.

The Dodge data bank includes breakdowns into 267 different structure types as well as dollar valuation, physical volume, number of dwelling units, number of stories, location of project, area in square feet, type of ownership, and framing description.[1] It also identifies and provides a mailing address for both the building owner and the architect. Reports are issued on a daily basis whenever changes occur throughout the life of the project. Usually projects enter the system and a report is issued when the owner first selects an architect. As significant events or milestones occur during the life of the project (e.g., schematic designs completed, project out for bid, or construction contract awarded), a new report is issued covering the event. A typical project may have a dozen reports issued through its lifespan. Dodge Reports will usually be received on a daily basis by mail from Dodge offices throughout the country and considerable screening may be necessary to identify those projects that meet the SIP criteria with respect to size, type, dollar valuation, ownership class, etc.

A recent innovation to the Dodge Reports system is the introduction of the Dodge Major Projects activity that focuses on projects having a dollar valuation of $500,000 or more.[2] Unlike Dodge Reports, Dodge Major Projects information is distributed to clients on a monthly basis using a computer format. Projects in the Dodge data base are screened by computer and only those that meet the client's specifications are reported. The monthly reports are tailored to provide only the information desired by the client. The advantage to using Dodge Major Projects is that for about the same cost as Dodge Reports (i.e., approximately $90,000 per year), the client can receive the desired information without having to manually review and screen the hundreds of thousands of Dodge Reports that are received annually. A disadvantage is that the Dodge Major Projects are issued on a monthly basis only, causing some delay in making contact with new owners and architects.

Dodge Reports and/or Dodge Major Projects (and their equivalents) provide a means for identifying new projects at an early design stage and provide information that would permit FEMA to contact the project owner and the project architect or designer. Use of Dodge Reports and/or Dodge Major Projects information would be desirable to provide a data base of projects initiated each year and provide a reference from which one can ascertain how well the Shelter Incentive Program is doing. Contact with owners and architects is needed so as to advise both parties of the Shelter Incentive Program and to encourage their participation if a voluntary type of Shelter Incentive Program is adopted or to provide basic information if a mandatory program is adopted. The contact would also indicate that the design firm should have a shelter analyst on their staff to help in the design process and to participate in the certification procedure that identifies the shelter protection included in the design. Should the design organization not have such an individual on their staff, then technical assistance would be made available by FEMA through a Shelter Advisory Center.

5.3 Shelter Advisory Centers

Incorporation of slanting techniques to include shelter in the design of new structures can be accomplished much more easily and economically if the design techniques are considered early in the design process. Once the design is finalized, architects and owners are reluctant to modify the design, since such changes are costly. If shelter is considered as part of the design requirement, it can usually be incorporated without adversely affecting the normal function or use of the space and at an economical and viable cost. Thus, advising the architectural team on the technical aspects of shelter and on slanting techniques early in the design phase of a project when the team still has an opportunity to consider design alternatives is an important aspect in administering a Shelter Incentive Program. One approach to providing such technical assistance to architects and other designers is to utilize Shelter Advisory Centers.

FEMA currently maintains a roster of specially trained architectural and engineering faculty located at various universities throughout the country. These instructors and professors are used to conduct courses in fallout shelter analysis and protective construction to resist blast and other nuclear weapons effects. They are knowledgeable in the technical aspects of shelter design and construction and can be utilized as a technical resource to advise architects and others involved in designing new structures.

The concept of providing shelter advisory services to the design community is not new. In 1965, OCD established a network of University Advisory Service

Centers. By 1970, there were 45 universities under contract to OCD that provided guidance and assistance to architects on a nationwide basis to incorporate fallout protection in the design of new facilities.[3] One university in each State was usually selected to service the design professionals in that State. Occasionally one university would service two States. The advisory centers were utilized most effectively with the introduction of a Direct Mail Shelter Development System (DMSDS) in 1968 wherein architects and building owners of new buildings were contacted by mail and urged to incorporate fallout protection in their designs. As part of the direct mail solicitation system, architects and building owners were offered technical assistance (at no cost to them) to facilitate incorporating the protective features. They were asked to contact the advisory service center in their State if such assistance was needed. Upon request, university staff would visit with the architect and provide whatever assistance was desired. To avoid any criticism from the architectural and engineering professional organizations, the University Advisory Service Center personnel would not engage in actual design. They were restricted to providing technical assistance and guidance, with the architectural team doing the actual design.

Given the nature of the distribution of new building projects between high risk areas (i.e., those places most likely to receive the direct nuclear weapons effects of blast, thermal and INR) and non-high risk areas, one soon realizes that the major requirement for technical assistance will be in the area of all-effects shelters. It is estimated that approximately 75 percent of new structures constructed each year are located in high risk areas. As a result, most of the technical guidance provided by the staff of the proposed Shelter Advisory Centers would be related to all-effects shelters as opposed to fallout protection. Unfortunately, the distribution of qualified instructors does not match this need.

There are about 450 faculty members currently included in the FEMA roster as having qualified to teach fallout shelter design and analysis courses. Of these, about 75 have participated in some aspect of the protective construction program and are familiar with design and analysis of all-effects shelters.[4] Additional efforts would be necessary to develop an improved capability to handle the guidance requirements for all-effects shelter in order to provide nationwide coverage.

5.4 Shelter Analyst Training

Since 1962, nearly 20,000 architects and engineers have been trained as fallout shelter analysts by FEMA and its predecessor agencies. Most were trained prior to 1970, when shelter analysts were utilized to conduct fallout shelter surveys of existing buildings. Since then, there has been a marked decline in the need for shelter analysts accompanied by an erosion in capability. Because of deaths, retirements, and the lack of new courses conducted, the number of active shelter analysts in 1985 has been reduced to about 10,000. Of these, perhaps 10 percent have participated in the FEMA sponsored Protective Construction Course and are knowledgeable in direct weapons effects including blast protection.[4]

For a Shelter Incentive Program to be viable, the program management system must develop a technical resource capability not only to design the needed shelter (be it fallout or all-effects), but also to certify that the desired shelter type, quantity of spaces, and protection level (i.e., designated Protection Factor or blast overpressure) was included in the final design. Some form of certification will be required to implement any of the shelter incentive program options under consideration. Shelter analysts can be used for both functions; shelter design and certification. However, it is likely that new training programs would have to be introduced to increase the number of shelter analysts with emphasis on blast shelter design and analysis, since that is where projected need is greatest and where existing resources are most limited.

To implement a training program would necessitate that training materials be updated to reflect current knowledge and capabilities. For example, procedures to calculate INR attenuation through concrete slabs and shelter openings are relatively new and not adequately covered in current texts and course materials. Designers of all-effects shelters would need to become familiar with such procedures and methodologies.

Training programs usually begin by first establishing a cadre of instructors and then training the instructors so they can train shelter analysts. "Train-the-trainer" programs are currently in vogue and would be quite applicable to the Shelter Incentive Program. A trained cadre of instructors already exists and could form the nucleus for any subsequent training.

Following the initial "train-the-trainers" courses, arrangements would need to be made for the "trainers" to conduct a series of protective construction courses (redesigned to reflect current techniques, methodologies, and procedures including the Shelter Incentive Program) which would help to alleviate the anticipated shortage of shelter analysts to handle all-effects shelter. These shelter analysts will be needed by design firms for shelter analysis work as well as shelter certification. It is anticipated that FEMA would accept certification only from shelter analysts who had demonstrated knowledge and technical expertise by successfully completing FEMA-sponsored courses. Each shelter analyst would be assigned a serial number for use in certification procedures.

Courses for shelter analysts could be conducted nationwide either as intense 2-week sessions or on a semester basis (i.e., one night a week for 15 weeks). The location of the courses should be at suitable colleges or universities nominated by the instructors or at cities where large numbers of engineers are located. Priority should be given to universities that will become the sites for Shelter Advisory Centers. See Figure 5.1 for the names of universities that were formerly in the program 15 years ago.

5.5 Typical Administrative Procedures

The flow chart in Figure 5.2 illustrates the relationship of an administrative process (for managing the Shelter Incentive Program) to the design and construction of a typical privately-owned project. The flow chart is divided into two parts. The upper part of the flow chart depicts the key events associated with the design and construction of a building or other facility. The lower part outlines the key events in the Shelter Incentive Program administrative process that parallel and interact with the design and construction events. Both kinds of events are keyed to a common numbering system to indicate their relationship. A time line extending over a period of two years shows the expected chronological order. A discussion of the 17 events shown in Figure 5.2 keyed to the event number follows:

(1) Owner Selects Architect. This event begins the process as indicated by zero time on the flow chart.

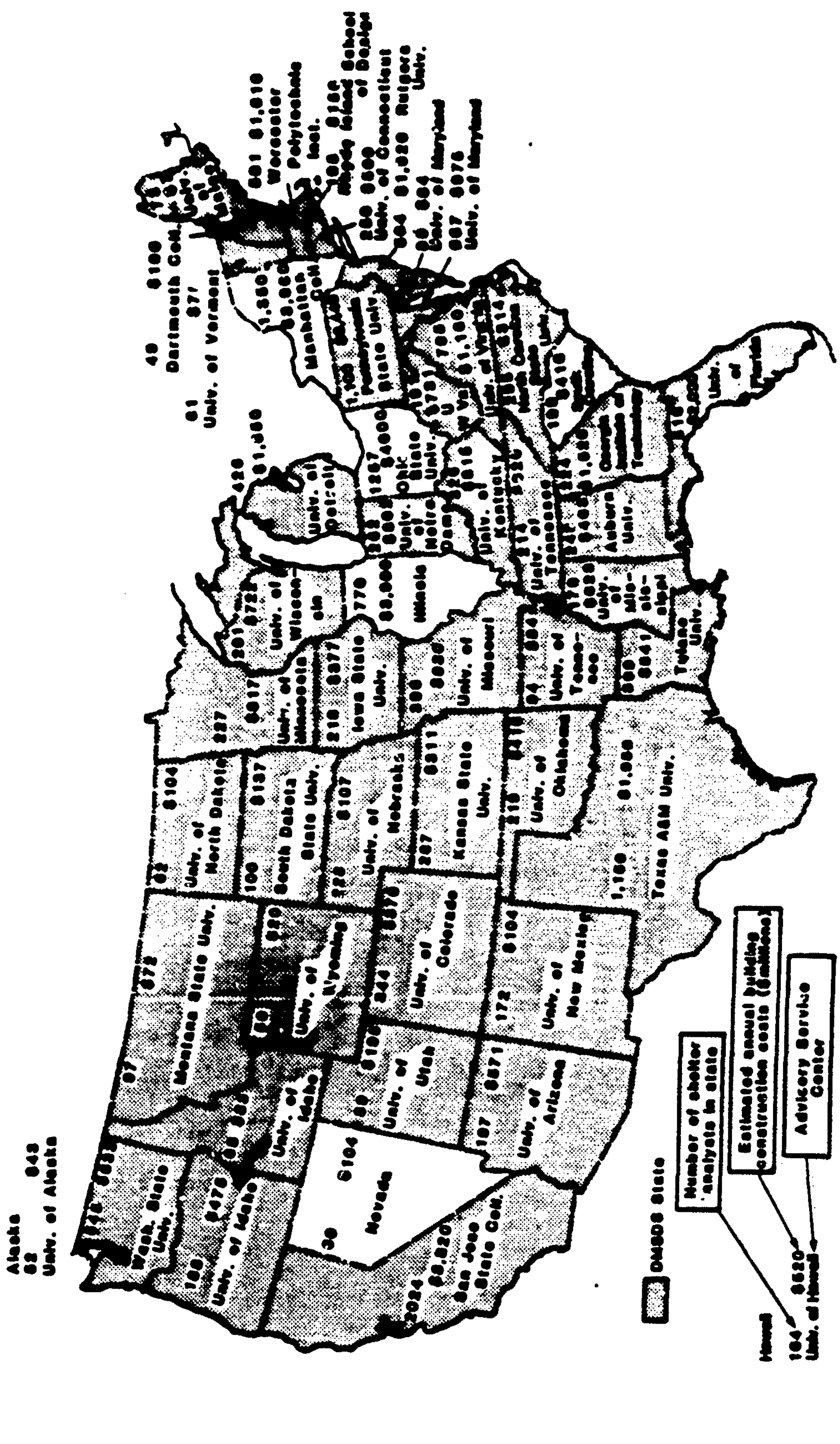

FIGURE 5.1: SHELTER DEVELOPMENT RESOURCES IN 1970

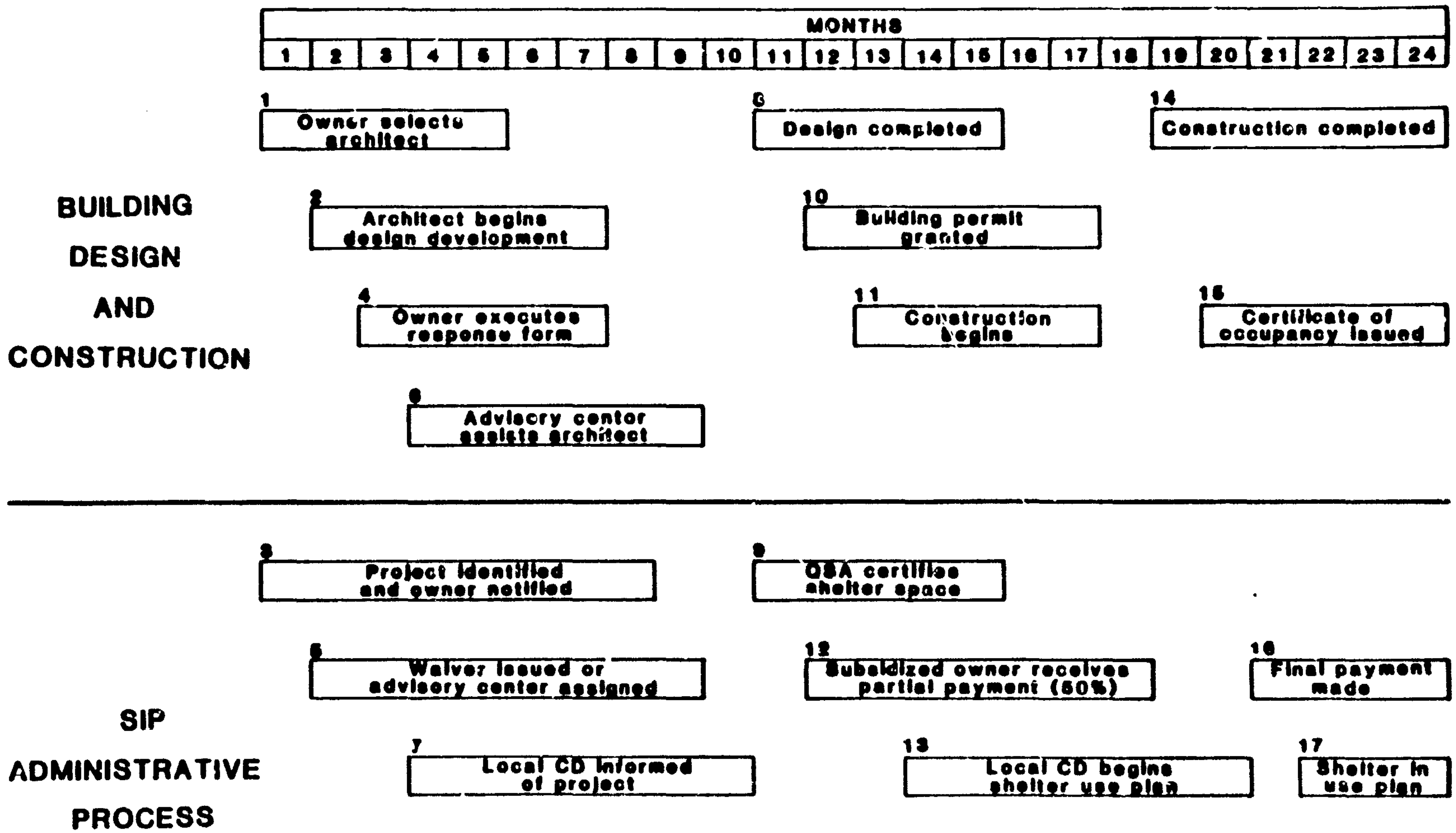

FIGURE 5.2: SHELTER INCENTIVE PROGRAM (SIP) FLOW CHART

(2) Architect Begins Design Development. Given the charge to design a building for a major use function and a specific site, the architect usually programs the project, assigns professional staff to the project, and begins to prepare schematic designs, fitting the proposed building to the site in the most advantageous way. It is at this early stage that the architect should consider the shelter protective requirements appropriate to the location of the project if he or she is to incorporate shelter at least cost to the owner. It is important for both the architect and the building owner to be aware of the details of the Shelter Incentive Program (voluntary or mandatory requirements depending on the program option finally selected), and for the design team to have a shelter analyst on their staff or available to them on a consulting basis that is knowledgeable on the kind of shelter needed at the project location.

(3) Project Identified and Owner Informed. This is the first event in the SIP administrative process and it should occur within the first month after the owner selects an architect. The activity is intended to assure that all owners and architects of new projects are aware of the incentives offered and sets in motion other activities of the administrative process such as payment procedures and provision of technical guidance and assistance to the design team. Briefly, the FEMA Program Office would subscribe to the Dodge Reports or Dodge Major Projects which identify new projects at an early design stage and provide the names and addresses of owners and architects. The approximate size, valuation, and location of the project are usually provided as well. Within a month to six weeks after the owner selects the architect, the FEMA Program Office would mail out an information packet on the SIP to the owner and architect. The information packet would cite the authority that established the Shelter Incentive Program and would contain the regulations that are in effect to carry out the program. If the zip code of the proposed construction is known, the owner/architect can be advised whether or not the building will be located in a risk area and provided appropriate guidance on slanting for all-effects shelter or fallout shelter. (Defining risk areas in terms of zip codes should facilitate emergency response planning and dispensing of guidance on the type of shelter needed for the project location.)

(4) Owner Executes Response Form. As part of the information packet in Step 3 above, the owner should be provided a response form to be filled in and

returned to the State Emergency Preparedness Office. (The volume of returns, estimated to range from 200-800 each working day, is too large to be handled at only one central collection point.) The response form should verify the location, valuation, size, and use class of the proposed project. Depending on the program option selected, the response form could serve other purposes as well. For example, for a mandatory shelter program, the response form could permit a determination as to whether the project meets the applicable provisions of a mandatory shelter law. It also could serve as a request for technical assistance, or a request for waiver to the provisions of the shelter law, or a notice of intent to request a subsidy payment authorized by the Shelter Incentive Program.

(5) Waiver Issued or Advisory Center Assigned. The data supplied by the owner (or architect) would be used at the State Emergency Preparedness Office to establish the status of the project depending on the option selected. For example, for a mandatory shelter law that established a project dollar valuation as a threshold for the mandatory shelter requirements (e.g., projects must cost over $200,000), those projects that prove too small to come under the mandatory shelter requirements would be dropped from the system and the owner/architect would be sent a letter to this effect. Similarly, those that request a waiver from the provisions of the mandatory shelter requirements would be given a provisional ruling, which might be appealed to the FEMA Program Office if adverse. Projects with approved waivers could be logged into a computerized data base for review by the FEMA Program Office. Local authorities might be consulted in arriving at a waiver decision but the ruling must be provided promptly so that the design process can proceed. Those projects that do not qualify for a waiver also would be logged into the SIP data base and assigned to the nearest Shelter Advisory Center by the appropriate State Emergency Preparedness Office.

If a voluntary program option is selected, the response form would indicate whether the owner/architect desires technical assistance to incorporate shelter and the appropriate Shelter Advisory Center would be notified of such a request. Generally, there would be one Shelter Advisory Center in each State with staff available to assist architects during the design process, train architectural staff members, and disseminate information on innovations, improved design procedures, and the like. Data on projects that accept the shelter incentive (voluntary program option) or those requiring a shelter subsidy (mandatory shelter option) would be used by FEMA to plan budget requests for the next fiscal year.

(6) Shelter Advisory Center Assists Architect. The Shelter Advisory Center staff would establish contact with the architect at the earliest possible design stage to assure that the architect had qualified personnel available and to offer any specialized assistance that might be needed where peculiar design problems are encountered. The professionals at the center often might visit the designers of larger projects during the design phase, which can take 10 months to a year to complete. Special attention should be paid to subsidized projects or projects that receive direct payment as an incentive since maximizing the shelter return is the prime objective. However, the Shelter Advisory Center should provide only advice, not actual design work.

(7) Local CD Informed of Project. The State Emergency Preparedness Office would be responsible for informing local jurisdictions of the existence of projects that are in the design phase and that will contain substantial amounts of public shelter. This information is needed so that the local emergency preparedness staff can begin to consider revisions in the jurisdiction's emergency response plan (i.e., concerning shelter use, staffing, and requisitioning of shelter supplies).

(8) Design Completed. The design phase is considered complete when detailed drawings, bills of materials, and specifications are sufficient to obtain the necessary building permits (or equivalent) and to solicit construction bids. For most projects, this point is reached about 10 months to one year after the owner selects an architect.

(9) Certification of Shelter Space. To all intents and purposes, practical compliance with the provisions of the Shelter Incentive Program is dependent on the design of the structure. In order to obtain the benefits available under a voluntary Shelter Incentive Program or be responsive to the requirements of a mandatory program, the owner of the project would be required to certify that the design of the structure complied with the shelter standards, implementing regulations or mandatory shelter law as applicable. Such certification should be submitted within a designated time period before or after construction has begun (if a voluntary Shelter Incentive Program) so that the procedures for

dispensing the "incentive" could be set in motion. For a mandatory shelter program, the owner certification should be submitted prior to inviting bids for the construction of the project and should be a condition for the granting of the building permit. In either case, the owner certification should be accompanied by a shelter analysis certification that includes a schematic drawing of each floor containing shelter space with the shelter areas clearly defined and a tabulation of the net available shelter area. This certification as to the type and level of protection, and number of shelter spaces provided in the design should be signed by a shelter analyst having a serial number assigned by FEMA.

(10) <u>Building Permit Granted</u>. In most localities, a building permit is required before construction can start on privately owned construction. The permit is based on inspection of plans and specifications to assure that codes, zoning restrictions, and other regulations to protect the public safety have been adhered to. For a mandatory Shelter Incentive Program, this step in the design and construction sequence provides a means for assuring program compliance. States can direct local jurisdictions to require the certification described above as a prerequisite to the issuance of the building permit.

(11) <u>Construction Begins</u>. At the time that the construction contract is awarded, the foregoing administrative process has assured that shelter has been considered in the design of those structures that are most likely to incorporate shelter protection. For a mandatory type program, the process assures that the project, if constructed in accordance to the plans and specifications, will contain the amount and kind of shelter space required.

(12) <u>Subsidized Owner Receives Partial Payment</u>. Because of the large expenditures of funds, and the relatively long time for the design and construction of a typical project, cash flow is a major concern for the building owner. To make a Shelter Incentive Program that provides a financial incentive to the building owner attractive, it is desirable that a procedure be devised which can provide financial relief to the building owner (i.e., compensation for the additional costs involved in providing the shelter protection) as soon as possible in the design and construction sequence, while at the same time assuring the Government that the structure being built does indeed have the protection being paid for. Advance payment could be made available to

those building owners who desire it at the beginning of the construction phase, or earlier if the design could be certified.

Advance payments might also be applicable under mandatory shelter programs because certain categories of building owners (e.g., local governments and qualifying non-profit institutions that construct schools, clinics and hospitals) may qualify for a Federal government subsidy to help pay for the increased building costs attributed to incorporating shelter. Owners of applicable projects that qualify for subsidy payments could apply for an advance payment at or before the beginning of the construction phase by submitting to FEMA the shelter certification (from the qualified Shelter Analyst) documenting the net available shelter area and the designed protective features. The payment would be made shortly thereafter and would be subject to recovery by the Government if the building were not completed or failed to pass final inspection.

(13) Local CD Begins Shelter Use Plan. Having received a copy of the certification, including plans of the shelter area then under construction, the local CD office (i.e., the local government agency responsible for emergency preparedness, response, and recovery) would be in a position to begin adapting the local shelter use plan to incorporate the new shelter space and to begin planning for marking, stocking, and managing the new shelter resource.

(14) Construction Completed. The construction phase for major projects may take a year or more. During the construction period, inspections are made by local building inspectors as well as by the architect. Quality and completeness of construction is controlled by these inspections.

(15) Certificate of Occupancy Issued. Upon completion of the project, a Certificate of Occupancy is issued by the local government authorizing the owner to occupy the structure.

(16) Final Payment Made. For a voluntary Shelter Incentive Program that includes a direct payment to the building owner or for projects that qualify for subsidy payments should a mandatory shelter option be selected, the final payment could be made by FEMA to the owner based on the issuance of a Certificate of Occupancy.

(70) Shelter In Use Plan. By the time the building is ready for occupancy, the local CD office should have executed a license for emergency use with the

building owners, incorporated the new shelter space in shelter use plans, obtained shelter supplies, and participated in a test of the shelter emergency power and ventilation. At this point, the design and construction process is complete.

5.6 Management Systems

One objective of a management system is to install the administrative apparatus needed to manage a shelter incentive program. This apparatus would be run primarily by FEMA Headquarters staff and would likely involve FEMA Regional staff and staff in the State Emergency Preparedness Offices, depending on the incentive option. For example, in a mandatory type of program, FEMA must deal with the problems and procedures concerning the issuance of waivers (i.e., exemptions from requirements of mandatory shelter regulations) that would not be encountered with voluntary incentive programs. Likewise, even under voluntary incentive programs, procedures and to some extent staffing, may be quite different for a program involving a direct payment to reimburse the building owner as opposed to a program providing a tax incentive to the owner.

As noted earlier, there are three basic functions that must be performed by a management system irrespective of the option. These are (1) identification of new design projects; (2) providing technical assistance and guidance to facilitate the incorporation of shelter protection; and (3) developing and maintaining a cadre of shelter analysts that can not only design the protective features, but also certify that the shelter was included in the design. In implementing these basic functions, the FEMA program office would have the option of contracting out specific procedures or doing them with in-house staff. For example, the process to identify new design projects and contacting the owners and architects of such projects urging them to consider shelter or advising them on mandatory shelter requirements could be accomplished with in-house FEMA staff. Letters and information packets could be readily dispatched by this staff. However, the procedure could also be contracted out. The F. W. Dodge Co. or some other organization could, under contract, provide these services if FEMA had staff ceiling problems that precluded a staff increase. Generally, "contracting out" is more costly than accomplishing the same task with in-house staff.

5.7 Administrative Program Costs.

The costs for managing a shelter incentive program can be broken down into the following categories:

(1) Project Identification. As noted earlier, the identification of new design projects and mail contact with the project owner and architect is an essential ingredient to any Shelter Incentive Program. Procurement of Dodge Reports is estimated to cost $90,000 annually and since the F. W. Dodge Company does not service Hawaii, another reporting source estimated to cost $10,000 would be required to achieve 50 State coverage. Staffing at FEMA Headquarters would require two professionals and eight clerical personnel to sort the reports, and mail the SIP information packets to the owners and architects. Annual personnel costs (including benefits) are estimated at $240,000. Costs for postage, envelopes, letters and printed information packets are estimated at $170,000. Total costs for personnel, materials, contracts, etc., for the Project Identification function are estimated at $510,000 annually. If FEMA contracted Project Identification to F. W. Dodge or another organization, personnel costs would decrease, but contract costs would increase and it is likely that the $510,000 overall estimate would be exceeded.

(2) Shelter Advisory Centers. Shelter Advisory Centers would provide technical assistance to design teams and would facilitate the incorporation of shelter into building designs. A center would be established at one university in each of the 50 States under a contract that averages $60,000 per year. FEMA Headquarters staffing would consist of two professionals and one clerical position to guide the effort and monitor progress (estimated cost of $113,000). It is also anticipated that there would be a three-day training program for the heads of each Shelter Advisory Center to acquaint them with their role in the Shelter Incentive Program at an estimated cost of $65,000. Total cost for personnel, materials, contracts, etc., for the Shelter Advisory Center function is estimated at $3,178,000 annually.

(3) Cadre Training. Current shelter analysts are familiar with fallout protection techniques but there is a relative shortage of analysts having knowledge of all-effects shelters and direct nuclear weapons effects that needs to be rectified in order to effectively implement a Shelter Incentive Program. Shelter Analysts would be required not only to design the shelters

in new facilities, but also to certify that shelter was included in a specific design. It is anticipated that in the first year of operation, approximately 200 courses would need to be conducted, most being on protective construction rather than fallout shelter analysis. The courses could be taught by an existing cadre of qualified instructors (for approximately $4,000 each) either on a semester basis (i.e., one night a week for 15 weeks) or as an intensive 2-week session. Curriculum development and publication of course materials would be accomplished by FEMA under contract and is expected to cost approximately $200,000. Staffing at FEMA Headquarters would require two professionals and one clerical to guide and monitor this function at an estimated cost of $113,000. In addition, it would be necessary to have a special 3-day training program for course directors (estimated at $65,000) and a 2-day updating workshop in about 150 different cities for shelter analysts wishing to participate in the program (estimated cost $300,000). Total annual costs for personnel, materials, contracts, etc., for the shelter analyst cadre training function are estimated at $1,478,000.

(4) FEMA Regional Program Support. Involvement of FEMA Regional staff would depend primarily on the shelter incentive option. For voluntary options, such as a tax benefit or direct payment to a building owner, it is anticipated that FEMA Regional staff involvement would be primarily directed to the Shelter Advisory Centers and cadre training programs. For a mandatory shelter program, it is anticipated that they would also become involved in processing owner response forms and managing operations in each of their States. It is estimated that one professional and one clerical position in each of 10 FEMA Regions would be required (under any option) at an estimated cost of $648,000 annually.

(5) State CD Program Support. Involvement of personnel at the State Emergency Preparedness Office also would depend on the shelter incentive program. Under a mandatory shelter option, State personnel would become more involved in contacts with owners and in processing response forms and requests for waivers. They also would work with local jurisdictions to assure that building permits are not issued unless a shelter certification or waiver had been approved. Under voluntary incentive options, their tasks would be reduced to monitoring the certification process and assigning projects to the Shelter Advisory Centers. It is anticipated that the following personnel requirements would be needed at each of the State Emergency Preparedness Offices:

(a) Voluntary Options: 1 professional and 1/2 clerical per State.

(b) Mandatory Option: 5 professional and 1 clerical per State. Personnel costs including salaries, travel and per diem would be on the order of $1,975,000 for all States under a voluntary shelter incentive option and nearly $8.5 million for a mandatory shelter option.

5.8 Summary of Administrative Program Costs.

Table 5.1 provides a summary of annual costs required to manage a Shelter Incentive Program. Total costs would range from approximately $7.8 million for a voluntary incentive program to $14.3 million for a mandatory program. The difference in costs is attributed to the increased staff required at each State Emergency Preparedness Office to administer a mandatory shelter program.

TABLE 5.1

SUMMARY OF SHELTER INCENTIVE PROGRAM MANAGEMENT COSTS

FUNCTION	STAFFING PATTERN	STAFFING COST ESTIMATE	SUPPORTING CONTRACTS	MISCELLANEOUS COSTS	TOTAL COSTS
A. FEMA HQ Staff					
(1) Project Identification	2 professional 8 clerical	$ 240,000	$ 100,000	$ 170,000	$ 510,000
(2) Shelter Advisory Centers	2 professional 1 clerical	$ 113,000	$ 3,000,000	$ 65,000	$ 3,178,000
(3) Cadre Training	2 professional 1 clerical	$ 113.000	$ 1,000,000	$ 365,000	$ 1,478,000
SUBTOTAL	6 professional 10 clerical	$ 466,000	$ 4,100,000	$ 600,000	$ 5,166,000
B. FEMA Regional Support	(per Region)				
(1) Voluntary Shelter Incentive Option	1 professional 1 clerical	$ 648,000	--	--	$ 648,000
(2) Mandatory Shelter Incentive Option	1 professional 1 clerical	$ 648,000	--	--	$ 648,000
C. State CD Support	(per State)				
(1) Voluntary Shelter Incentive Option	1 professional 1/2 clerical	--	$ 1,875,000 1/	$ 100,000	$ 1,975,000
(2) Mandatory Shelter Incentive Option	5 professional 1 clerical	--	$ 8,250,000 1/	$ 200,000	$ 8,450,000
TOTAL	(1) Voluntary	$ 1,114,000	$ 5,975,000	$ 700,000	$ 7,789,000
	(2) Mandatory	$ 1,114,000	$12,350,000	$ 800,000	$14,264,000

1/ Personnel for State support are provided through Comprehensive Cooperative Agreement (i.e., Contract effort).

SECTION V REFERENCES

1. Dodge Construction Potentials: Defining Potential For Your Products, F. W. Dodge Division, McGraw-Hill Information Systems Co., N.Y., N.Y.

2. The Manager's Tool Box, F. W. Dodge Division, McGraw-Hill Information Systems Co., N.Y., N.Y.

3. Highlights: Experimental Fallout Shelter Grant Program, Department of Defense, Office of Civil Defense, February 1970.

4. Personal Communication with Mrs. Anita Bibb, Federal Emergency Management Agency, May 1985.

SECTION VI

ALTERNATIVE PROGRAM DESIGNS

6.1 Common Features

In this section, we describe and discuss a structured set of shelter incentive programs that would, to various degrees, be suitable for implementation in conjunction with or in anticipation of a decision to deploy some form of ballistic missile defense. The purpose of the shelter system produced by a shelter incentive program would be to improve population survival both from the detonation of missile warheads penetrating the proposed missile defense system and from the detonation of weapons delivered by other means (aircraft, cruise missiles, FOBs, etc.). Clearly, the variables discussed in earlier sections would allow the consideration of a very large number of alternative programs, each with its own costs, benefits, and feasibility. To reduce this universe of programs to manageable size and to focus the discussion on the issues defined in the Statement of Work, all of the program options presented have certain common features that will not be varied. These common features and the reasons for choosing them are:

(a) Scope. All programs are intended to apply to all 50 States and the District of Columbia. Data on construction volume apparently does not cover Hawaii but the omission cannot have a significant impact on the projections of slantable construction used here. Indeed, one can postulate adding Puerto Rico and other U.S. possessions without having to modify the results.

(b) Risk Areas. All programs postulate the production of all-effects (blast) shelters in certain defined "risk areas" and fallout shelter elsewhere. In support of the regulations and enabling legislation governing any of these programs, FEMA would need to define the areas within which all-effects shelters would be specified. The areas undoubtedly would be composed of both military targets and urban concentrations of population and industry. As discussed in Section I, FEMA TR-82 is of such a nature. Any revision of the current risk areas is likely to maintain this character. However, in this study we will use the urbanized areas of the 1980 census as the stand-in for a more complex definition of risk areas. The main reasons for this choice are that key construction and population data can be associated with urbanized areas and that the overwhelming majority of the population considered at risk in the current FEMA risk areas are residents of urbanized areas. Thus, there is a rough correlation between urbanized areas and current or future specified risk areas. This is not to say that all 1980 urbanized areas are considered to be necessarily at risk. Some, such as Atlantic City, Ocala, and Harlingen-San Benito, have little but population as a target value. On the other hand, military targets not associated with urbanized areas are in sparsely settled locations and do not contribute much to either population or construction in the risk areas. Therefore, the risk areas used in this study are urbanized areas containing 61 percent of the population, 56 percent of the buildings built annually, and 73 percent of the annual construction value, as shown in Table 2.6

(c) Protective Criteria. All-effects shelter in these candidate programs will provide balanced protection against the direct effects of a 1-megaton surface burst at 30-psi blast overpressure range. The unit cost of this protection when included in the normal building design, based on the limited cost analysis of Section III, is taken to be $27 per square foot. The blast protection criterion chosen is the highest for which slanting guidance is available. It has been chosen because, as shown in Figure 1.2, the proportion of the population likely to experience an overpressure greater than 30 psi is small. Further increases in protection generate diminishing returns. The cost-benefit ratios for 30-psi and 20-psi shelters for the population distribution in Figure 1.2 are nearly identical but the 30-psi shelter provides substantially higher absolute life-saving performance. Moreover, as shown in Figure 1.1, a 30-psi shelter is likely to remain intact at ground zero for an air-burst detonation. The cost differential for the increased protection is not large. Program costs estimated in this section can be reduced by less than 20 percent if 20-psi shelter is assumed.

Fallout shelter in these candidate programs would provide a protection factor (PF) of 100 against fallout radiation. We do not believe that the minimum PF of 40 currently used to rate inherent shelter is adequate for a purposeful slanting program. Moreover, because of the need to consider the multi-hazard use of the shelter space generated by an incentive program, the location of the induced fallout shelter must be in a basement or sub-basement; that is, inherent space on upper floors of buildings would not qualify for incentive payment nor would it satisfy a mandatory requirement. In other words, any multi-hazard shelter generated by the candidate programs would be located in building basements in all cases. The cost of PF 100 fallout shelter, based on the cost analysis of Section III, is taken to be $5 per square foot or about one-fifth the cost of all-effects shelter. This cost includes emergency power generator and the same ventilation and other necessities included in the shelter standards of Appendix B.

(d) Shelter Space Allocation

In all cases, a shelter space will be equivalent to 10 square feet of usable floor area except in hospitals and nursing care facilities where 50 square feet will be allocated to one patient plus one attendant (25 square feet per person). For practical purposes, unit costs multiplied by 10 will represent the cost per person sheltered.

6.2 Definitions

To minimize ambiguity in the description of alternative shelter incentive programs, the following definitions have been adopted. These definitions are believed to be consistent with the data that will be used to evaluate and assess these programs.

(a) Building Project

A project is a new building, addition, or modification or a group of buildings built contemporaneously by or for a specific developer under common financing arrangements. This definition is intended to cover residential developments and mixed-use developments as single projects.

(b) Project Cost

The cost of a building project is the total cost less the cost of land, architectural fees, equipment, and offsite improvement.

(c) Shelter Cost

The cost of incorporating space meeting the shelter standards of Appendix B into a building project by modification (slanting) of the building design is determined by comparison of the estimated project cost with and without the shelter features. This cost may be expressed as a unit cost (cost per square foot of shelter space), as a cost per shelter space, assuming 10 square feet of net floor area per person, or as a percent or fraction of project cost, assuming a stated amount of shelter space.

(d) Public Shelter

Shelter areas of buildings to which members of the general public have access when shelter protection is needed.

(e) GNP Cost

The estimated total dollar cost of a shelter incentive program, assuming a stated yield in all-effects and fallout shelter spaces, including the increased construction costs, incentive premiums paid, if any, and management and administrative expenses.

(f) Budget Cost

The estimated total dollar cost of a shelter incentive program to the Federal government, assuming a stated yield in all-effects and fallout shelter spaces, including appropriated funds expended and tax revenues forgone, as appropriate.

(g) Certification

A written statement by a qualified person of the number and location of shelter spaces designed or built to meet at least the minimum standards.

6.3 Alternative Programs

In the remainder of this section, eleven alternative shelter incentive programs are presented, using a common format. A finder list of programs identified by short title will be found in Table 6.1. Thereafter, each program design is identified by program number and short title, followed by summary information on purpose, owner participation, project categories included, incentive structure, minimum project size, minimum shelter capacity, shelter cost ceiling, other limitations, estimated annual shelter yield, estimated annual GNP cost, estimated annual budget cost, and any special features of the program design. Finally, each program design contains a discussion of the implications of the design features, an explanation of the basis for the estimates, and a summary of perceived advantages and disadvantages.

TABLE 6.1

FINDER LIST OF PROGRAM DESIGNS

PROGRAM DESIGN NO. 1

MANDATORY SHELTER IN FEDERAL BUILDINGS

Purpose: To exhibit Federal leadership, train the A&E profession, and gain cost and technical experience.

Owner Participation: Federal agencies and private developers intending to lease buildings to Federal agencies.

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Mandatory, subject to minimum project size, shelter cost ceiling, and other bases for exemption. Interagency transfer of incremental shelter cost. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor area unless the building is a residence. Residences are exempted if they contain less than 5 dwelling units and are part of a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons or project occupancy, whichever is larger.

Shelter Cost Ceiling: 7 percent of project cost for minimum capacity.

Other Limitations: Exemptions if additional shelter not needed or public shelter operationally impractical.

Estimated Annual Shelter Yield (spaces): 575,000 all-effects; 100,000 fallout.

Estimated Annual GNP Cost: $166 million.

Estimated Annual Budget Cost: $151 million.

Special Features:

(1) Require accurate incremental shelter cost data.

(2) No State participation in management.

Discussion:

This program is limited to new construction by Federal agencies and by private developers building facilities intended for long-term lease to Federal agencies. As such, the program does not generate much new shelter as compared with the need but it is nevertheless an extremely important program because it demonstrates that the Government is serious about the need for the inclusion of multi-hazard shelter in new construction. It is unlikely that the States would mandate shelter in their construction programs unless the Federal Government does so. On the other hand, the Federal Buildings Program could generate considerable additional shelter-building at the State and local levels of government and possibly by some organizations in the private sector. Such reactions were seen 20 years ago while H. R. 8200 was being considered. This program is similar to the proposed Section 206 in that bill.

Thousands of architects and engineers are engaged in the design of new buildings for the Federal Agencies. If this were the only program adopted initially, it would be a good vehicle for increasing the knowledge and expertise in the A&E profession and initiating the search for innovative cost-cutting approaches to the slanting of new construction. Moreover, a year's operation of this program could generate a wealth of cost data to augment the limited case studies now available. A mandatory program is the only way to include Federal buildings in a larger shelter incentive program, such as the one proposed in H. R. 8200. Therefore, it should be continued to exhibit Federal leadership even when professional training and cost experience are no longer critical needs.

In this program, we propose that funds sufficient to cover the anticipated shelter costs be requested and appropriated to FEMA, who would then transfer the funds as needed to the Federal agencies, mainly DoD and GSA. This would obviate the need for individual congressional committees to authorize and appropriate funds for the inclusion of shelter in individual projects.

The minimum project size is taken as 5,000 square feet of floor area rather than a cost figure because unit costs are likely to vary with the kind of building and its location as well as with inflation. The minimum size chosen is designed to exempt buildings or alterations so small that a 50-person shelter (500 sq. ft.) would be uneconomic, 50 persons being the minimum capacity allowable. Residences, such as military housing, are exempted if they contain less than 5 dwelling units and are not part of a residential construction project containing 20 or more units. In the latter case, a shelter for 50 persons or the number of prospective occupants must be provided, probably in the basement of one or more of the proposed buildings.

Projects also are exempted if the incremental shelter cost, as audited by FEMA, exceeds 7 percent of project cost. As can be seen in Table 3.6, this is most unlikely to occur where fallout shelter is the requirement. However, in risk areas costs exceeding 7 percent could occur in some low-cost commercial-type construction, such as small warehouses, as indicated in Table 3.5. The only other bases for exemption are that more than enough shelter already exists in the vicinity of the building site or that incorporation of public shelter would interfere with the essential operations in the facility during a nuclear or peacetime emergency.

The estimated shelter yield from this program was determined in the following way: The potential shelter yields for the several building categories in Tables 2.7 and 2.8 were reduced by factors obtained from Table 2.11 to account for the exemption of buildings having a floor area less than 5,000 square feet. For example, Table 2.7 projects a total of 1.37 million shelter spaces for office buildings. The average floor area for this building category is 10,270 square feet, as determined by dividing the total floor area in the category by the number of projects. The minimum size, 5,000 sq. ft., is .49 of this average. In Table 2.11, it is observed that buildings having less than this fraction of the average account for 9 percent of the valuation and, hence, floor area and shelter spaces. There remain 91 percent of the shelter spaces or 1.25 million. Continuing this calculation yields an overall potential of 9.45 million all-effects shelter spaces and 1.81 million fallout shelter spaces. If we assume that Federal construction is typical of all construction, then Table 2.12 suggests that seven percent of the annual spaces will be in Federal buildings except for one-family developments. Deleting this contribution to annual spaces, we find that 7 percent of the remainder is 588,700 all-effects shelter spaces and 102,900 fallout shelter spaces. However, some small number of Federal construction projects, mainly defense facilities, are likely to be exempted because of excessive cost or operational impracticality. Hence, these figures have been reduced by about 3 percent and rounded to those shown.

The annual GNP cost has been calculated by multiplying all-effects spaces by $270 ($27 per sq. ft.) and fallout spaces by $50 ($5 per sq. ft.) to yield a cost of $160.25 million. To this amount has been added $5.75 million in management and administration costs, based on the estimates in

Section V. No State participation is proposed in this program.

The annual budget cost differs from the GNP cost because it is assumed that 10 percent of the spaces are in buildings built by private developers and leased to the Federal government. These costs are recovered by higher lease payments over a ten-year period.

In summary, the advantages and disadvantages of this program are:

(a) Advantages

1. Demonstrates Federal resolve and leadership.

2. Provides convenient startup mode for management and technical assistance programs.

3. Will impact a substantial part of the A&E profession.

4. Will test shelter regulations and technical assistance procedures.

5. Should provide good cost data for blast slanting program.

6. May yield technical improvements to lower costs later.

7. May encourage State shelter laws.

(b) Disadvantages

1. Provides only a minor improvement in shelter posture.

2. Is credible only as first step in a full-scale program.

3. Is vulnerable to federal budgetary and appropriations cutbacks.

4. Does not gain experience with important construction classes; e.g., single-family houses.

PROGRAM DESIGN NO. 2

MANDATORY SHELTER IN ALL BUILDINGS

Purpose: To radically improve the protection available to the population over a decade or two by mandating the inclusion of multi-hazard shelters in virtually all new buildings.

Owner Participation: All

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Mandatory, subject to minimum project size, shelter cost ceiling, and other bases for exemption. No Federal subsidy. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor area unless the building is a residence. Residences are exempted if they contain less than 5 dwelling units and are part of a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is larger.

Shelter Cost Ceiling: 7 percent of project cost for minimum capacity.

Other Limitations: Exemption may be granted if additional shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 7,570,000 all-effects; 1,760,000 fallout.

Estimated Annual GNP Cost: $2.15 billion

Estimated Annual Budget Cost: $160 million

Special Features:

(1) Federal buildings used to monitor shelter costs.

(2) Voluntary home shelter program encouraged.

Discussion:

This program is an extension of Program 1 to all new construction. The Federal government would pay the costs of administering the program and the costs of incorporating shelter in Federal buildings but no Federal subsidy would be provided to others. The full range of technical assistance discussed in Section V would be provided. In general, the bases for exemptions from the legal requirement are the same as in Program 1. In summary, projects of less than 5,000 square feet in floor area and small residences would be exempted because the minimum requirement for 500 square feet of shelter area (50 spaces) would be unduly burdensome. Similarly, the limitation to 7 percent of building cost impacts mainly on all-effects shelter in commercial structures and possibly some smaller apartment buildings (see Table 3.5).

The assumed occupancy for commercial buildings used in this analysis (60 square feet per person) applies only to selling areas. If the facility is not used for retail trade, the 10 percent of floor space criterion would likely prevail. Under this criterion, the 7-percent limitation is likely to be exceeded only for the smaller establishments. Nonetheless, we judge that about 75 percent of the shelter potential in the commercial category would be exempted. This is reflected in the annual shelter yield estimate. In estimating annual shelter yield, the procedure described in the discussion of Program 1 was followed except that 75 percent of commercial spaces were deleted from the all-effects tally rather than merely 24 percent resulting from the exemption of buildings of less than 5,000 square feet. One-family residential developments are, however, included in this program.

The GNP cost is obtained by multiplying the 7,570,000 all-effects spaces by $270 and the 1,760,000 fallout spaces by $50. To these costs are added $14.26 million in administrative costs. The annual Federal budget cost includes only these administrative costs and the cost of incorporating shelter in Federal buildings. The main cost is reflected in the economy and, on the average, amounts to a 2.3 percent increase in construction costs.

An assumption underlying these estimates is that no owner will incorporate more shelter space than required by law. As a consequence, the annual yield would forecast at least 20 years before a substantially complete shelter posture would be achieved. As noted in Section II, regional variations in new construction rates alone make it unlikely that a complete shelter system can be developed by means of slanting new construction.

In summary, the advantages and disadvantages of this program are:

(a) Advantages

1. Assures inclusion of shelter in most new construction.

2. Minimizes Federal budget cost and hence is less vulnerable to appropriations cutbacks.

3. Should yield technical improvements to lower costs since owners must absorb all costs and will try to minimize them.

4. Increases construction costs less than 3 percent on the average.

(b) Disadvantages

1. Owners will incorporate the minimum shelter capacity required regardless of shelter need.

2. Enforcement will be costly and require State and local cooperation.

3. Legality of mandate similar to clean air, clean water will be tested in court.

4. Still takes 20 years to achieve good shelter posture.

PROGRAM DESIGN NO. 3

MANDATORY SHELTER EXCLUDING SMALL RESIDENTIAL

Purpose: To improve the protection afforded the population by mandating the incorporation of multi-hazard shelter in all new construction except small residences.

Owner Participation: All

Projects Included: All new buildings and alterations and modifications to existing buildings except residential structures containing less than 5 dwelling units.

Incentive Structure: Mandatory, subject to minimum project size, shelter cost ceiling, and other bases for exemption. No Federal subsidy. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor area.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is larger.

Shelter Cost Ceiling: 7 percent of project cost for minimum capacity.

Other Limitations: Exemptions are available if additional shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 6,530,000 all-effects; 1,420,000 fallout.

Estimated Annual GNP Cost: $1.85 billion

Estimated Annual Budget Cost: $160 million

Special Features:

(1) Federal buildings used to monitor shelter costs.

(2) Voluntary home shelter program included.

Discussion:

This program differs from Program 2 only in that single-family homes, duplexes, triplexes, and fourplexes are excluded from the mandatory shelter requirement partly because it is difficult and expensive to incorporate multi-hazard shelter in these small residences and partly on the privacy principle:

"A man's home is his castle." Thus, all new shelter will be found in nonresidential buildings, multifamily housing, and nonhousekeeping residential structures. To compensate somewhat for the exclusion of small residences, a program encouraging homeowners to acquire home shelters and home buyers to demand shelter in new residences is included.

A comparison of the estimated shelter yield for this program with that of Program 2 will show that an estimated 1,040,000 all-effects spaces and 340,000 fallout spaces attributable to one-family residential developments have been deleted and the GNP cost reduced accordingly. The annual Federal budget cost is not affected. No credit is given in these estimates for shelter induced voluntarily by the home shelter assistance effort. It might well be substantial, especially where only fallout protection is required. As with Program 2, this program would require about two decades to achieve a good multi-hazard shelter capability.

In summary, the advantages and disadvantages of this program are essentially the same as in Program 2.

PROGRAM DESIGN NO. 4

MANDATORY SHELTER WITH SUBSIDY

Purpose: To radically improve the protection provided the population by requiring the slanting of most new buildings and providing a cost-sharing subsidy.

Owner Participation: All

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Mandatory, subject to several bases for exemption. Federal Government provides grants to State and local government and loan subsidies to private sector to defray half the shelter cost.

Minimum Project Size: 5,000 square feet of floor area unless the building is a residence. Residences are exempted if they contain less than 5 dwelling units and are part of a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is larger.

Shelter Cost Ceiling: None

Other Limitations: Exemption may be granted if additional shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 9,170,000 all-effects; 1,760,000 fallout.

Estimated Annual GNP Cost: $2.58 billion

Estimated Annual Budget Cost: $1.3 billion

Special Features:

(1) Federal buildings used to monitor shelter costs.

(2) Voluntary home shelter program included.

Discussion:

The intent of this program is to make a mandatory shelter program more palatable to State and local governments and the private sector by sharing the cost of incorporating shelter in new construction. For illustrative purposes, the cost-sharing formula is 50 percent, which has been traditional in U.S. civil defense programs. It could be some other formula, such as the 90-10 formula used in Federally supported highway construction.

The basic approach of cost sharing is that costs will be minimized because the owner has to share part of the costs. There is no need to put a ceiling on the shelter cost because of this fact. On the other hand, the shelter yield is limited because the cost-sharing owner is unlikely to incorporate more shelter than is required by law.

With 50-50 cost sharing, the incremental cost to the owner for fallout shelter will be very low. Some public sector agencies, such as school boards, may convert large fractions of new school floor space to shelter in these circumstances, as has been done in the past (see Table 1.1, for example). Cost sharing for all-effects shelter will reduce owner costs for shelter in commercial properties to 5-6 percent of project costs and much less in other building categories.

In this program, grants are made to State and local governments, their instrumentalities, and qualifying nonprofit institutions (IRC 501(c)3) on the basis of approved designs at the start of construction. Equivalent loan subsidies are provided to profit-making entities and non-qualifying nonprofit organizations. This arrangement parallels that of Program 8 and the discussion of that program should be consulted.

The estimated annual shelter yield for this program is based on Tables 2.7 and 2.8 except that the potential shelter yield has been modified to account for the 5,000-sq.-ft. threshold by the method described in Program 1 and the result reduced by 3 percent to account for the effect of other bases for exemption. No additional shelter has been included to account for the possibility that some projects, such as schools, may contain more than the minimum shelter capacity.

The GNP cost was obtained by multiplying the all-effects shelter yield by $270 and the fallout shelter yield by $50, then adding $14.3 million for administrative costs. The annual budget cost is half the assumed shelter cost except for the fully funded Federal buildings plus the administrative costs.

In summary, the advantages and disadvantages of this program are:

(a) Advantages

1. Assures inclusion of shelter in most new construction by mandate.

2. Establishes joint civil defense responsibility by cost-sharing formula.

3. Should encourage efforts to control cost since owners must pay half.

4. Increases cost to owners by only about 1 percent of project cost for all-effects shelter; much less for fallout shelter.

5. Legality of cost-sharing mandate established by Civil Defense Act.

(b) Disadvantages

1. Owners will incorporate the minimum shelter capacity required because of cost except possibly for fallout shelter in schools and other public facilities.

2. Enforcement will be costly and require State and local cooperation.

3. Grant and loan subsidy administration must be prompt and efficient.

4. Program exceeds a billion dollars in the Federal budget each year; would be vulnerable to appropriation vagaries.

5. Still takes 20 years to achieve good shelter posture.

PROGRAM DESIGN NO. 5

MANDATORY SHELTER WITH NONPROFIT SUBSIDY

Purpose: To improve the protection afforded the public by requiring shelter in in most new buildings and subsidizing the costs to nonprofit entities.

Owner Participation: All in mandatory requirement; State and local governments, their instrumentalities, and IRC Section 501(c)3 organizations in subsidy program.

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Mandatory, subject to several bases for exemption. Federal government provides grants to state and local governments and qualifying nonprofit entities to cover full cost of shelter, subject to cost ceiling.

Minimum Project Size: 5,000 square feet of floor area unless the building is a residence. Residences are exempted if they contain less than 5 dwelling unts and are part of a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is larger.

Shelter Cost Ceiling: $270 per space for all-effects shelter; $50 per space for fallout shelter for subsidy payment.

Other Limitations: Exemptions may be granted if additional shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 11,520,000 all-effects; 2,550,000 fallout.

Estimated Annual GNP Cost: $3.0 billion

Estimated Annual Budget Cost: $1.33 billion

Special Features:

(1) Federal buildings used to monitor shelter costs.

(2) Voluntary home shelter program included.

Discussion:

This program is a mandatory, multi-hazard version of the H.R. 8200 proposal in concept. Shelter is mandated in all new buildings, subject to limited bases for exemption. However, a subsidy is established that is applicable to State and local governments, their instrumentalities, and nonprofit organizations meeting the requirements of Section 501(c) and 170(c) of the Internal Revenue Code. This subsidy covers the incremental cost of including shelter in buildings constructed for these owners, subject to a cost ceiling of $270 per all-effects space and $50 per fallout shelter space. Owners that do not qualify for subsidy must bear the cost of incorporating shelter into their buildings, passing the increased cost on to their customers.

According to Table 2.12, we can assume that 44 percent of the annual valuation and, hence, floor area will qualify for the subsidy payment. The other 56 percent will be in the private sector. These owners can be expected to encourage innovative design and technology to reduce the costs of complying with the law. This technology is readily transferred to the public sector by the means described in Section V, thus reducing the Federal subsidy cost. At program startup, we estimate that the average all-effects shelter space will cost $250; the average fallout space, $45.

The unsubsidized owners can be expected to limit their costs by incorporating the minimum shelter capacity required by law. In the subsidized sector, however, Federal underwriting of full costs should foster the inclusion of more shelter in schools and other government buildings. Although the increased amount of shelter induced by the subsidy is difficult to estimate, we believe that the amount of shelter included in office-type buildings will double and that fully 40 percent of the floor area in educational buildings will be converted to shelter. These projections are reflected in the estimated annual shelter yields.

The GNP cost has been obtained by costing each all-effects space at $250 and each fallout space by $45. The management costs of approximately $14 million are added. The Federal budget cost represents 44 percent of the GNP shelter cost plus management costs.

In summary, the advantages and disadvantages of this program are:

(a) Advantages

1. Assures inclusion of shelter in new construction by legal mandate.

2. Has the appearance of fairness by underwriting the cost of shelter in new schools, hospitals, etc.

3. Will improve the cooperation of States and local governments.

4. Should yield technical improvements to lower costs since private sector must absorb shelter costs.

5. Produces a good shelter posture in less than 15 years.

(b) Disadvantages

1. Private owners will incorporate only the minimum shelter capacity.

2. Enforcement may be costly.

3. Legality of mandate similar to clean air, clean water will be tested in court.

4. Program exceeds a billion dollars in the Federal budget each year; may be vulnerable to appropriation vagaries.

PROGRAM DESIGN NO. 6

PUBLIC HOUSING PROGRAM QUALIFICATION

Purpose: To obtain additional shelter where needed, and to gain cost and technical experience by making shelter slanting a prerequisite to Federal assistance in housing programs.

Owner Participation: All developers, public and private, desiring to participate in Federal housing programs.

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Qualification prerequisite, subject to minimum project size, shelter cost ceiling, and other bases for exemption. Cost of shelter allowed in project cost basis for assistance. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor area except that residences are exempted if they contain less than 5 dwelling units and are in a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is larger.

Shelter Cost Ceiling: 7 percent of project cost for minimum capacity.

Other Limitations: Exemptions if additional shelter not needed.

Estimated Annual Shelter Yield (Spaces): 915,000 all-effects; 270,000 fallout.

Estimated Annual GNP Cost: $ 267 million.

Estimated Annual Budget Cost: $11.5 million

Special Features:

(1) Mandatory Shelter in Federal Buildings (Program 1) must be combined with this program.

Discussion:

This program requires the incorporation of shelter in all housing projects receiving Federal financial assistance that are above the minimum project size and below the shelter cost ceiling. These projects are supported by the Federal government in order to achieve a public good (the creation of housing) and offer developers a profitable return on investment that would not be achievable without the Federal support. Thus, it seems equitable to require developers to provide another public good (incorporation of shelter) in return.

No payment, direct or indirect, specifically related to the cost of incorporating shelter will be made. However, the project cost on which Federal assistance will be based will be allowed to include $270 per space for all-effects shelter, and $50 per space for fallout shelter for the specified minimum shelter capacity unless the allowance for shelter exceeds 7 percent of the cost of the project including the shelter allowance. This allows the developer the same rate of return on the investment in shelter as on other project costs. This inclusion of shelter cost will likely increase the sale or rental price of the dwelling units and may render some projects uneconomic, especially those already at the margin. On the other hand, these effects should be less than they would be if cost of shelter were not allowed in total project cost.

The Federal housing program activity in 1983 ($17.841 billion, Table 4.1) was 23 percent of the total housing construction in 1983 ($77.500 billion, Table 2.4). Thus the projected annual shelter yield is taken as 30 percent of the potential total yield, assuming the minimum project size and using the methods described in the discussion of Program 1. The estimated number of all-effects spaces was reduced by about 3 percent to allow for the possibility that some multi-family projects could be exempted because of the 7 percent shelter cost ceiling. Of course, the estimated yield is based on the assumption that the Federal housing programs would continue at the 1983 rate of activity.

The GNP cost estimate combines all-effects shelter (915,000 x $270 = $247.0 million) and fallout shelter (270,000 x $50 = $13.5 million) plus $5.8 million for Federal management expense and $2.0 million for State management expense (Table 5.1). In the Budget cost estimate, the cost attributable to shelter would equal (a) the difference between market interest rate and housing program interest rate for loans and (b) the administrative cost for loan guarantees. It can be seen in Table 4.1 that loans were about 20 percent of the activity. Thus the Budget cost would be for loans, 0.20 x $260.5 million x 0.03 = $1.6 million, the interest cost, and, for loan guarantees, 0.80 x $260.5 million x 0.01 = $2.1 million, the administrative cost, for a total of $3.7 million plus the $5.8 million for Federal management and $2.0 million for State management.

In summary, this program is addressed to that part of the housing development industry that receives Federal financial assistance. Its potential production of added shelter is relatively low (about 1.2 million spaces per year) but so is its Budget cost (about $11.5 million per year).

(a) Advantages

1. It provides entry into the largest potential source of shelter to be obtained by slanting: housing.

2. It can provide accurate cost and technical data on slanting for a category of projects for which no such data now exists.

3. It provides a defined target; housing developers who already have a financial incentive in proceeding with the projects.

(b) Disadvantages

1. It may result in causing some developers not to proceed with proposed housing projects, thus partially defeating the housing incentive programs.

2. Its management cost is relatively high compared to the potential production of shelter.

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PROGRAM DESIGN NO. 7

FLAT INCENTIVE PAYMENT

Purpose: To maximize the amount of shelter voluntarily included in new construction through generous payment, minimum red tape, and technical assistance.

Owner Participation: All except Federal agencies (Program 1).

Projects Included: All new buildings and alterations and modifications to existing buildings except where additional shelter not needed or hazardous material or processes present.

Incentive Structure: Federal government offers to pay at construction start $30 per square foot for all-effects shelter in risk areas; $6 per square foot for fallout shelter in other areas. Technical assistance provided.

Minimum Project Size: None

Minimum Shelter Capacity: 50 persons, 10 percent of floor area or project occupancy, whichever is greater.

Shelter Cost Ceiling: None

Other Limitations: Must meet minimum shelter standards.

Estimated Annual Shelter Yield (Spaces): 29 million all-effects; 11 million fallout.

Estimated Annual GNP Cost: $9.07 billion

Estimated Annual Budget Cost: $9.07 billion

Special Features:

(1) Must be combined with Program 1 to cover all buildings and exert Federal leadership.

(2) Includes voluntary home shelter program.

Discussion:

The essence of this program is to give building owners "an offer they can't refuse" to include multihazard shelter in their new construction. By offering a generous flat payment irrespective of the actual incremental cost of shelter, one that obviously will return more than the cost of including shelter, most owners should be motivated to include as much shelter as is possible consistent with the other requirements for the structure. Most schools will go underground. Commercial centers will emulate the Kansas City underground shopping area. Office buildings will take advantage of the fact that only the upper slab of a multi-level basement need be designed to resist the blast loading.

From the Government's point of view, the program is a matter of going out and buying the shelter where it is needed, paying a reasonable profit as with anything else it buys. The cost, even when offering a premium price, is a fraction of the cost of acquiring land and building single-purpose shelters that could be a "white elephant" with no economic utility.

Estimating the amount of shelter that might be generated annually in this fashion is a matter of judgement. After reviewing building practices and prior behavior, we have concluded that a flat payment of $5 to $10 per square foot above shelter cost might generate the following shelter proportion of total floor area: Office buildings, 35-40 percent; Commercial buildings, 60-65 percent; Manufacturing facilities, 50 percent; Educational facilities, 75-80 percent; Hospitals and Health facilities, 50-60 percent; Other Nonresidential structures, 30-50 percent. For residential buildings, we think that traditional requirements for windowed areas are likely to continue to dominate this kind of construction so that the potential shelter is unlikely to be significantly more than those shown in Tables 2.7 and 2.8. Using the floor area data from these tables for nonresidential construction and the above estimates, it appears that this program could generate 28 million all-effects shelter spaces in other than Federal buildings, at least during the first few years of operation. This annual production would produce a good shelter posture in many, if not most, risk areas in a period of 5 years or so. As discussed in Section II, regional and local variations in construction rates make it unlikely that a well-balanced capability could be generated nationwide.

The program also could generate about 11 million fallout shelter spaces yearly outside of risk areas, which, together with existing and inherent fallout spaces, could largely eliminate shelter deficits within a decade.

This is a $9 billion a year program, adding 5 percent to the national construction expenditure. After the first three years, costs would decrease as opportunities for new construction in shelter-deficit areas became less prevalent. Based on a requirement for shelter for about 250 million persons, the mature program would cost approximately $50 billion over a 5-10 year period.

In summary, the advantages and disadvantages of this program are:

(a) Advantages

1. Offers the most likely means of improving the protection of the population over the short term.

2. Provides a good shelter posture in less than a decade.

3. Avoids legal and enforcement problems associated with a mandatory program.

4. Management procedures should be relatively simple.

5. Should encourage efforts to control actual shelter costs since owners can improve profit thereby.

6. Program cost is modest compared to active strategic defense costs and minor compared to total defense expenditures.

(b) Disadvantages

1. Requires a very large appropriation compared to past CD programs.

2. Premium payment is open to charges of "boondoggle", etc.

PROGRAM DESIGN NO. 8

GRANT PLUS LOAN SUBSIDY

Purpose: To obtain radical improvement in the protection provided the population by subsidizing the incorporation of shelter in new construction.

Owner Participation: All except Federal agencies.

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Grants to State and local governments and qualifying nonprofit institutions plus loan subsidies for all other owners to defray the actual incremental cost of shelter. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor area except that residences are exempted if they contain less than 5 dwelling units and are in a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor areas, or project occupancy, whichever is largest.

Shelter Cost Ceiling: None except that incentive payments are limited to $270 per space for all-effects shelter and $50 per space for fallout shelter.

Other Limitations: Not eligible if additional shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 10,945,000 all-effects; 2,450,000 fallout.

Estimated Annual GNP Cost: $2.86 billion

Estimated Annual Budget Cost: $2.86 billion

Special Features: Mandatory shelter in Federal buildings must be combined with this program.

Discussion:

This program is a modification of Program 7. The Federal government will pay to the owner the actual cost of adding shelter (up to a specified maximum) plus the costs of administering the program. The full range of technical assistance discussed in Program 1 will be provided.

Payments will be made in the form of grants to State and local governments and to health and welfare and other nonprofit institutions as defined in Paragraph 4.2. These grants will be made available at the start of construction. Payments will be made in the form of loan subsidies to all other owners. The amount of the loan subsidy will be equivalent to the amount of a grant, had a grant been made. Loan subsidies are available at the start of construction. Making funds available at the start eliminates the necessity for the incentive to cover the interest the owner would have had to pay on the funds expended for slanting and thus reduces the budget cost of the program.

Payments will be based on the estimated incremental cost of the slanting. However, the payments will be limited to a maximum of $270 per space of all-effects shelter and $50 per space of fallout shelter for all needed shelter spaces included in the project that are certified by a qualified shelter analyst to meet the requirements at the location of the project.

The estimated annual shelter yield is based on Tables 2.7 and 2.8 as modified to allow for the effect of the 5,000 sq. ft. threshold by the method described in Program 1 and further reduced by 3 percent to allow for the effect of other exclusions. Undoubtedly, some owners would not participate. On the other hand, experience has shown that some 40 percent of the floor area of schools would be built underground, providing about 1.6 million all-effects spaces and 0.6 million fallout spaces. Similarly, 20 percent of office floor area would be built as shelter, doubling the estimated shelter yield to 2.5 million all-effects spaces and 0.6 million fallout spaces.

With payments limited to actual cost rather than the flat rate, the cost of all-effects shelter should average $250 per space and that of fallout shelter, $45 per space. Thus, the GNP cost of all-effects shelter would be 10,945 x $250 = $2.74 billion and that of fallout shelter 2,450,000 x $45 = $0.11 billion. To this is added $7.8 million for program management for a total GNP cost of $2.86 billion. In this program, the Budget cost would be the same as the GNP cost.

In summary, this voluntary program applies to all owners except the Federal government (Program 1). This cost is limited to the actual cost of slanting with specified maximum costs per space but there is no limit on the number of space per project. Failure of some owners to participate would be offset by an increase in the number of spaces incorporated by others.

(a) Advantages

1. The opportunity for an owner to make a profit on slanting is limited.

2. The yield would be increased because of additional shelter incorporated in schools and office buildings.

3. Increases construction cost less than 3 percent on the average.

4. Reduces time to achieve good shelter posture to less than 15 years.

(b) Disadvantages

1. Program managememt would be more difficult because of the need to verify "actual cost" estimates.

2. Is vulnerable to federal budgetary and appropriation cutbacks.

3. Still takes longer than a decade to achieve a good shelter posture.

PROGRAM DESIGN NO. 9

LOAN AND LOAN SUBSIDY

Purpose: To obtain radical improvement in the protection provided the population by underwriting the cost of slanting of new construction.

Owner Participation: All except Federal agencies.

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Low-cost loans to State and local governments and qualifying nonprofit institutions plus loan subsidies to all other owners to defray the actual incremental cost of shelter. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor space except that residences are exempted if they contain less than 5 dwelling units and are in a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy whichever is largest.

Shelter Cost Ceiling: None except that incentive payments are limited to $270 per space for all-effects shelter and $50 per space for fallout shelter.

Other Limitations Not eligible if additional shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 10,945,000 all-effects; 2,450,000 fallout.

Estimated Annual GNP Cost: $2.86 billion

Estimated Annual Budget Cost: $2.86 billion

Special Features: Mandatory shelter in Federal buildings must be combined with this program.

Discussion:

This program is the same as Program 8 except that the incentive for State and local governments and qualifying nonprofit institutions is in the form of low-cost loans instead of grants. All other owners would be offered loan subsidies.

The low-cost loan would be for the full cost of the project including the actual cost of shelter. The interest rate on the loan would be set below the market so that the present value of the difference between the interest paid and the interest that would have been paid would equal the cost of shelter. This loan would then be sold in the secondary market at its discounted value. Thus, the net cost to the Federal government would be equal to what the grant would have been.

In summary, the advantages and disadvantages of this program would be the same as for Program 8.

PROGRAM DESIGN NO. 10

PUBLIC SECTOR GRANT

Purpose: To achieve improvement in the protection provided the population by providing a subsidy to some owners to slant the design of new construction.

Owner Participation: State and local governments and qualifying nonprofit organizations.

Projects Included: New buildings and alterations and modifications to existing buildings.

Incentive Structure: Grants to participating owners equal to the cost of adding shelter.

Minimum Project Size: 5,000 square feet of floor area, except that residences are ineligible if they contain less than 5 dwelling units and are in a project containing less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is largest.

Shelter Cost Ceiling: None except that incentive payments are limited to $270 per space for all-effects shelter and $50 per space for fallout shelter.

Other Limitations: Not eligible if additional shelter not needed, public shelter operationally impractical or building houses hazardous materials or processes.

Estimted Annual Shelter Yield (Spaces): 5,340,000 all-effects; 1,340,000 fallout.

Estimted Annual GNP Cost: $1.41 billion

Estimated Annual Budget Cost: $1.41 billion

Special Features: Mandatory shelter in Federal buildings must be combined with this program.

Discussion:

This program is similar to Program 8 except that it does not offer loan subsidies to private owners. It resembles the program of H.R. 8200 in 1963.

As in Program 8, schools, which are practically all covered by this program, would produce about 1.6 million all-effects spaces and 0.6 million fallout spaces. Except for schools, the public sector (excluding the Federal government) would produce about 40 percent of the shelter production of Program 8 (3.74

million all-effects spaces plus 0.74 million fallout spaces). Adding school shelter gives a total yield of 5.34 million all-effects spaces and 1.34 million fallout spaces. The example offered by the governments might induce some private owners to incorporate shelter but the amount would not likely be significant.

At average costs of $250 per space for all-effects shelter ($1.34 billion) and $45 per space for fallout shelter ($0.06 billion) plus $7.9 million for program management, the GNP cost of this program would be $1.41 billion per year.

In summary, this program is addressed to the public sector whose responsibility for protection of the population was established in P.L. 920, the Civil Defense Act of 1950.

(a) Advantages:

1. It eliminates the need for trying to induce the private sector (56 percent of the total potential) to incorporate shelter.

2. It demonstrates leadership by government.

(b) Disadvantages:

1. It increases the time to achieve a good shelter posture to almost 30 years.

PROGRAM DESIGN NO. 11

PUBLIC SECTOR GRANT PLUS TAX CREDIT

Purpose: To achieve substantial improvement in protection for the population by subsidizing the incorporation of shelter in most new buildings.

Owner Participation: All except Federal agencies.

Projects Included: All new buildings and alterations and modifications to existing buildings.

Incentive Structure: Grants to State and local governments and qualifying nonprofit institutions plus a tax credit for all other owners equal to the incremental cost of shelter. Technical assistance provided.

Minimum Project Size: 5,000 square feet of floor area except that residences are ineligible if they contain less than 5 dwelling units and are in a project that contains less than 20 dwelling units.

Minimum Shelter Capacity: 50 persons, 10 percent of floor area, or project occupancy, whichever is largest.

Shelter Cost Ceiling: None, except that incentive payments are limited to $270 per space for all-effects shelter and $50 per space for fallout shelter.

Other Limitations: Not eligible if shelter not needed, public shelter operationally impractical, or building houses hazardous materials or processes.

Estimated Annual Shelter Yield (Spaces): 10,945,000 all-effects; 2,450,000 fallout.

Estimated Annual GNP cost: $2.98 billion

Estimated Annual Budget Cost: $2.98 billion

Special Features: Mandatory shelter in Federal buildings must be combined with this program.

Discussion:

This program is similar to Program 8 except that a tax credit equal to the incremental cost of shelter is offered to private owners instead of a loan subsidy.

The significant feature of this program is the introduction of the tax credit. This renders program management somewhat less burdensome because it eliminates the need for buying the loans and selling them in the secondary market which is necessary in the loan subsidy incentive. Also, research indicates that builders are most satisfied by the use of a tax credit. In general, however, the performance of this program should be similar to Program 8.

On the other hand, the cost of this program would be somewhat greater than that of Program 8. There would be a delay of about a year between the time the private developer invested his money in shelter construction and the time at which he would realize the tax credit. The interest on the investment for that period would be a real cost of incorporating shelter. Therefore, the costs of this program were estimated on the basis of $270 per space in all-effects shelter and $50 per space in fallout shelter for private owners as opposed to $250 and $45 in Program 8.

Although the annual budget cost of this program is nearly $3 billion, the funding request to the Congress would be only about half this amount. The majority of the shelter space would be developed by the private sector and their costs would be reflected in lower Federal revenues because of the tax credit. This probably would constitute an advantage for this program over Program 8. Otherwise, the advantages and disadvantages of this program appear similar to those of Program 8.

SECTION VII

EVALUATION OF ALTERNATIVE PROGRAMS

7.1 Limitations of the Analysis

In some measure, any evaluation of the shelter incentive programs described in Section VI will be conditioned by the quality of the information on which they are based. Since quantitative figures on potential shelter yields and costs tend to have considerable influence on evaluative judgments, it is useful to review critically the basis for quantification and how it might affect the findings and conclusions of the study.

The dimensions of this project did not permit a major and detailed examination of annual construction data. We worked with summary data published by McGraw-Hill's Dodge-Sweet Divisions and with summary printouts provided by the Bureau of the Census. The Dodge construction estimates provided the data on contract valuation and floor area and, hence, the unit costs for building construction, as shown in Table 2.1. These data were presented as "1983 preliminary" data but more complete tabulations were unavailable during the study period. However, the unit costs appeared reasonable and use of incomplete or preliminary data should impart a conservative bias to the construction estimates.

The Dodge summary data also provided information on numbers of dwelling units and therefore the average floor area and cost of these units. But no information on numbers of projects or average project valuation was provided in the estimates. For this information, we turned to the Bureau of the Census building permit data. These data, summarized in Table 2.2, also were known to be incomplete and they recorded only buildings whose owners were required to obtain a building permit. The Census data gave numbers of buildings and valuation, the latter of which could be compared with the Dodge data, once differences in definitions of categories were understood and accounted for. Overall, the relationship between the two sets of data was reasonable: The building permit valuation was less than the Dodge valuation and the differences were greatest in the building categories where government projects tend to dominate; namely, schools and hospitals (Table 2.3). Nevertheless, the Census overall valuation was higher than our estimates of government ownership (Table 2.12) would suggest and in one category, Manufacturing, the Census valuation exceeded the Dodge valuation by nearly 50 percent! One option would have been to increase the Dodge "preliminary" 1983 figures somewhat on the basis of these considerations, but, as can be seen in Table 2.3, the more conservative approach was taken. Accordingly, our "average year" valuation and floor area estimates are probably somewhat conservative for the year 1983. To the extent that 1983 was really an "average year," the estimates of shelter yield in Section VI may be somewhat low.

The real concern about the Census building permit data lies in the number of buildings recorded. This information, together with valuation, allows determination of the average cost per building, and, using the Dodge unit cost data, the average building floor area. This information was useful in weeding out small use categories and alterations that would not be susceptible to slanting technology but, even after the geographic data were applied to differentiate between the larger urban projects and the smaller rural projects, the average project sizes turned out to be uncomfortably low (Tables 2.4, 2.7, and 2.8). For example, the few case studies on which all-effects slanting costs are based (Table 3.1) are based on shelter areas that for the most part would be associated with buildings much larger than the average sizes derived from the Census data. One possible explanation could be that costs for building permit purposes are routinely understated but this variation would have to be very large to account for this difference. The problem is further complicated by the decision to truncate the assumed distribution of cost per building (Table 2.11) at three times the average. In almost every category, buildings are commonly observed costing 10 and 20 times the average costs derived from the Census data. Fortunately, the high end of the distribution was not used in the analysis. Primarily, the low end was used to determine the loss in potential shelter caused by setting the minimum project size at 5,000 square feet. If the use of the Census data underestimates the average size of buildings or the assumed size distribution places too much valuation in the small size range, again our projections of annual shelter yield may be somewhat low.

In estimating incremental shelter costs for all-effects shelter and their relationship to total project costs, we have depended on the case studies of Murphy et al. These studies were done in 1969 and have been subject to peer review for over 15 years. The methodology has been accepted and incorporated into FEMA guidance. Since 1969, building costs have tripled but the data for adjusting costs are readily available. Nonetheless, the basis for estimating the all-effects costs is not robust, especially at the 30-psi blast overpressure level. One would prefer many more case studies, more attention to cost-saving technology, and, above all, some actual building of blast-slanted basements. On the whole, however, we judge that the costs used in this study are on the high side compared to what is likely to be the consequence of deployment of any of the alternative programs.

Finally, a real limitation to the analysis was the general lack of data or evidence on the rate of participation of owner groups in subsidy programs as a function of the amount of subsidy. All of our gleanings are recorded in Section IV. In exploratory visits to the Department of Housing and Urban Development, officials indicated that such relationships were not a priority subject of study. Subsidies either worked or didn't work or were set by other criteria. The evidence did indicate that the public sector has been much more cooperative than the private sector but that additional costs were usually "a prohibiting factor" in most cases. An exception appears to be schools (Table 1.1) where the design benefits of underground construction is increasingly accepted, especially in tornado-prone areas.

Six of our eleven program designs are mandatory in nature and full owner participation is a reasonable assumption if the bases for exemption are not trivialized. Program Design No. 7, Flat Incentive Payment, is the only candidate program designed to make participation a profitable venture. If the cost variations in Table 3.1 are approximately correct, participation in such a program is increasingly profitable the larger the project or the more that the building becomes shelter, or both. This dynamic is the essence of the free enterprise system. How rapidly shelter would be produced is highly judgmental at best but our estimates in Section VI could be underestimates. On the other hand, Program Design Nos. 8 through 11 are all versions of a program limited to actual shelter cost or its present-value equivalent. We assume general participation, which could happen in the right societal context since the prohibiting factor of cost has been eliminated. However, with no possible profit motivation, a major part of the private sector, at least, may choose not to participate for a variety of reasons. If half the private sector failed to participate, shelter yields would be reduced by more than a quarter.

7.2 Characterization of the Alternatives

The eleven alternative programs described in Section VI employ a variety of incentives and address all classes of owners in a variety of patterns, as shown in Table 7.1. Five of the programs include a mandatory requirement, Program 1 applying to Federal agencies only and Programs 2 through 5 applying to all owners. However, we are convinced that none of the other candidate programs, with the possible exception of Program 7, will be effective unless Program 1, Mandatory Shelter in Federal Buildings, is made a part of the total package.

Programs 4, 5, 8, 10, and 11 provide grants to State and local governments and to nonprofit health and welfare institutions. Program 9 provides low-cost loans to these same owners in lieu of grants. Programs 4, 8, and 9 provide loan subsidies to nonqualifying nonprofit institutions and private entrepreneurs and Program 11 provides tax credits to these same owners in lieu of loan subsidies. Program 6 requires owners, public and private, who participate in Federal housing programs to incorporate shelter in their projects. Program 7 provides grants to all owners except the Federal government.

The Accelerated Cost Recovery (ACRS) incentive described in Section IV was not included in any of the program designs because it was found that developers prefer tax credits and loan subsidies. Therefore, it appeared that the ACRS would not be productive and, in addition, would likely entail greater costs in the long run.

As noted earlier on, the variables in this study could spawn a very large number of distinguishable program alternatives. To lay all of these out would only "hide the forest for the trees." Many of the unstated alternatives are obvious by inspection once the thrust of a program design is known. For example, Program 7 employs grants only but similar programs can be devised using loan subsidies or tax credits for the private sector so long as these have a comparable effect to the grant and are not tied to incremental shelter costs but rather offer a profit incentive. The main purpose of some of the program designs is to exhibit the main characteristics of important variations.

7.3 Comparison of Alternative Programs

The yields and costs of the alternative programs are compared in Table 7.2, in which the programs are ranked in descending order of estimated annual

TABLE 7.1

OWNER PARTICIPATION BY TYPE OF INCENTIVE

Type of Incentive						
Program	Mandatory	Program Qualification	Grant	Low-Cost Loan	Loan Subsidy	Tax Credit
1	②					
2	①					
3	①					
4	①		③		④	
5	①		③			
6		⑤	③ ④			
7			③			
8					④	
9			③	③	④	
10			③			
11						④

Class of Owner (see Paragraph 4.2)

① All

② Federal Government

③ State and Local Governments and Health and Welfare Institutions

④ Other Nonprofit Institutions and Private Entrepeneurs

⑤ All owners participating in Federal Housing Programs

TABLE 7.2

COMPARISON OF ALTERNATIVE PROGRAMS

Program No.	Program Title	Annual Yield (Spaces) All-Effects (millions)	Annual Yield (Spaces) Fallout (millions)	Annual Program Cost GNP ($ bill.)	Annual Program Cost Budget ($bill.)	Cost per Space GNP ($)	Cost per Space Budget ($)
7.	Flat Incentive Payment*	28.58	11.10	9.24	9.22	233	232
5.	Mandatory Plus NonProfit Subsidy	11.52	2.55	3.00	1.33	213	95
8.	Grant Plus Loan Subsidy*	11.52	2.55	3.03	3.01	215	214
9.	Loan and Loan Subsidy*	11.52	2.55	3.03	3.01	215	214
11.	Public Sector Grant Plus Tax Credit*	11.52	2.55	3.15	3.13	224	223
4.	Mandatory With Subsidy	9.17	1.76	2.58	1.30	236	119
2.	Mandatory Shelter in All Bldgs.	7.57	1.76	2.15	0.16	230	17
3.	Mandatory Excluding Small Res.	6.53	1.42	1.85	0.16	233	20
10.	Public Sector Grant*	5.92	1.44	1.58	1.56	214	212
6.	Public Housing Qualification*	1.49	0.37	0.43	0.16	243	90
1.	Mandatory in Federal Bldgs.	0.58	0.10	0.17	0.15	246	224

*Includes Program 1

shelter yield. It will be noted that the estimated yields and costs for all of the voluntary programs (6 through 11) include the yield and cost of Program 1, Mandatory Shelter in Federal buildings. This reflects the predication of the yields of these programs on clear Federal leadership and commitment. (Mandatory shelter in Federal buildings is part of all mandatory programs.)

Program 7, the profit-making alternative in which the Government sets out to buy shelters as it would bombers and submarines, generates the highest yields and consequent program costs. The average cost per shelter space, however, is not exorbitant and less than some alternatives. This is a program of nearly $10 billion annually that accomplishes its purpose in a period of 5 years, more or less. This is a planning horizon comparable to that of the much less costly crisis relocation program that the Carter and Reagan adminstrations have attempted to get funded by the Congress. It is also comparable to that of the much more costly Strategic Defense Initiative, should a deployment decision be reached.

Next below Program 7 are four programs judged to produce about the same amount of new shelter. These have been ranked in Table 7.2 by least cost. Program 5, one of the mandatory programs, is ranked first. It is less costly, especially to the Federal budget, because the private sector is unsubsidized. Grants for shelter cost to state and local governments and nonprofit entities should make this program relatively popular politically. The Federal budget cost is only 1 1/3 billion dollars, in the region of some of the outyear costs presented to the Congress in recent years. Of the other programs of equal productivity, special attention might be paid to Program 11, which, although the most costly, hides a majority of its budget cost in the form of lost revenue from the tax credit. Hence, the required annual appropriation is not much more than that for the mandatory program, Program 5. The other two voluntary incentive programs are frankly $3 billion dollar a year programs. They cost one-third of Program 7 and produce 40 percent of its new shelter. These four programs must operate over a decade to produce a reasonable shelter posture. By "reasonable," we mean that sufficient shelter will become available in the Sunbelt and most large cities, many other localities will be able to shelter their population by crowding, and serious deficits will be found mainly in decaying, blighted areas where evacuation or single-purpose shelter is the only likely solution.

The remaining Programs in Table 7.2 consist of mandatory programs and programs dealing only with some ownership classes. They produce progressively less new shelter although some have quite modest Federal budget costs compared to the more productive programs. Their value depends in part on the Government's policy objective and in part on how they can be combined with other programs or program features.

7.4 Program Combinations

Some of the program alternatives can be combined (we have added Program 1 to all other programs in Table 7.2 in which it is not already included). And, as noted before, some program features, such as tax credits, can be substituted in or added to selected programs. These combinations may be of interest for a variety of reasons. They may be perceived as being more acceptable to Congressional committees that must pass on annual authorizations and appropriations. They may be more attuned to Administration policies and active defense schedules. They may be combined to create a more palatable or understandable program at the State and local level. Finally, they may be considered as a "nested" set of options that can be proposed in logical succession to best accomplish an objective or to deal with legitimate objections to other courses of action.

The most obvious combination of the latter kind is to deploy Program 1 initially and to expand to one of the more productive programs a year or two later when the management and technical assistance mechanisms are in place, better cost data are in hand, and the benefits and feasibility of program expansion are more demonstrable and credible. Another important alternative, if total deployment time is of critical interest, would be deploy Programs 1 and 10, the mandatory Federal shelter program and the public sector grant initially, with the option to expand to the flat incentive payment scheme as soon as technical and cost experience warranted. This type of approach was essentially that behind H.R. 8200, which, it will be recalled, passed the House of Representatives in 1963 and probably would have become law if President Johnson had continued the Kennedy support of the proposal. Of course, the concept of paying a premium over cost to obtain more shelter in new construction was not proposed at that time but it cannot be ruled out if approaches had been made to the private sector.

7.5 Preferred Shelter Incentive Program

The Statement of Work for this study calls for "a recommended optimum program design." We know of no methodology for determining the optimality of any shelter incentive program and any preference expressed here must be interpreted in light of our perceptions of the rational objective of any shelter incentive program. As to objective, we assume that the intent of the Government is to achieve a reasonable level of shelter protection for the population within a reasonable period of time, say, less than a decade. On this basis, the Flat Incentive Payment program, Program 7, is recommended in preference to any of the other programs. On the other hand, it is essential to get better cost data before setting the flat payment and this depends also on improving the technical assistance basis for the program. If a sufficient market develops, private entrepreneurs can be counted on to offer blast doors, blast valves, and the like at very competitive prices. The engineering profession also can be counted upon to develop cost reduction techniques in other areas. For this purpose, it is recommended that Programs 1 and 10 be deployed initially for at least two years. This approach would yield about 15 million shelter spaces (all-effects plus fallout) over the two-year period at a cost of about one and one-half billion per year. Assuming that the results were as promising as we expect, a flat payment incentive could be offered thereafter. This incentive would likely achieve the Government's intent over the next four to five years, probably at a cost substantially less than indicated in Table 7.2, especially if the incentive payment were "fine-tuned" annually on the basis of cost data and analysis of the production level of new shelter.

The legislation needed for this approach is very similar to the House-passed H.R. 8200. Indeed, the first two-year increment differs only in minor detail. A draft of legislation for the flat incentive payment program is contained in Appendix D.

SECTION VIII

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

On the basis of this analysis, the following conclusions are drawn:

1. **Multi-hazard shelter incentive programs are a feasible means of improving the in-place protection provided the U.S. population against** a wide variety of peacetime and wartime hazards. However, the approach of slanting the design of new construction to incorporate multi-hazard shelter is unlikely to achieve a uniform level of protection throughout the country because of significant regional variations in the annual amount of new construction. In some areas of the Northeast and Midwest, incentives must be continued and shortfalls covered by single-purpose or expedient shelter construction and evacuation plans.

2. The technology for full slanting of new construction exists but experience is based on a limited number of case studies. These studies indicate that the current unit cost of all-effects shelter in building basements varies with the size of the shelter area and may average $25 per square foot additional cost to meet the standards set in this study. The incremental cost of basement fallout shelter meeting the specifications set in this study is estimated at $5 per square foot.

3. There have been no successful shelter incentive programs in the United States. Successful shelter incentive programs in European countries are mandatory in nature, usually with government cost-sharing. However, our conclusion is that an appropriately designed flat incentive payment for the voluntary incorporation of multi-hazard shelter in new construction will generate much more shelter space annually and will avoid the problems intrinsic to mandatory programs at a modest increase in the cost per shelter space.

4. A multi-hazard shelter incentive program carried out to maturity is estimated to cost $40 billion to $46 billion, assuming a target of 150 million all-effects shelter spaces and 100 million fallout shelter spaces. The time period required is estimated to range from as little as 5 years for a flat incentive program to as long as 30 years for a limited cost-only

incentive program for the public sector. Clearly programs of this magnitude would be recommended by the Administration and approved by the Congress only under circumstances quite different from those existing today.

8.2 Recommendations

The following recommendations are offered for consideration:

1. FEMA should maintain a capability to describe, explain, and justify multi-hazard shelter incentive programs for policy planning purposes.

2. FEMA should invest at least in research to improve all-effects slanting technology and in case studies to improve the basis for design standards and costing. In addition, an experimental program to incorporate all-effects shelter in a limited number of Federal buildings should receive serious consideration.

3. Pending the outcome of further study, the design standards proposed in this study should be adopted.

APPENDIX A

STRUCTURE SHIELDING ANALYSIS FOR INITIAL NUCLEAR RADIATION

This schematization of the analysis of the structure shielding provided by a simple structure against the initial nuclear radiation from the detonation of a nuclear weapon is based on the work of L. V. Spencer (Nuclear Science and Engineering, 57, 129 154, 1975), and C. M. Eisenhauer (unpublished NBS report). The components of the initial nuclear radiation (INR) of concern include: (a) gamma radiation from the fission products emitted from the developing and rising fireball during the first minute, (FPG); (b) "secondary" gamma radiation produced by the interaction of neutrons with nitrogen in the air (ASG); neutrons emitted from the detonating weapon, (N); and gamma radiation produced by the neutrons in interactions with the materials of the walls and floors of the structure (NGAM). Because of the differing nature of the interactions of each of these components due to their nature, energies, and angular distributions, each of the components must be treated separately in the calculation of their attenuation.

The shielding afforded by a structure is calculated in terms of a quantity called "reduction factor", (RF). Each of the above mentioned components will have their own RF, e.g., RF_{FPG}, RF_N, etc. Further, the roof and walls of the structure are treated separately and the respective RFs added, e.g., $RF_{WN} + RF_{RN} = RF_N$. The final RF of the structure, presently calculated only for the central location on a given floor, is the sum of the individual RFs for each component of the INR plus that of the NGAM. (The RF for NGAM is defined as the ratio of the dose from gamma radiation produced by neutron interactions in the roof and walls and the incident neutron radiation -- rather than the incident gamma radiation.) However, the sum must be a weighted sum using the fractional part of the total INR dose (outside) represented by each component. The NGAM RF has the same weighting as its source, namely the neutrons. Alternatively, the individual doses for each component plus the NGAM may be calculated for the inside position and then added directly.

The form of the expressions used to calculate the RFs for the components are similar and the distinction between them will be made using the designators FPG, ASG, N, and NGAM. The reduction factor for a component, i.e., the ratio of the dose at the designated point in the structure to the free field dose is calculated from the product:

$$RF = M * B(X) * G(X,\omega) \quad (1)$$

In the equations X will designate the thickness of a wall, a roof, or an overhead slab in pounds per square foot of concrete. A slab 12 inches thick has X = 144 pfs. X_r, X_e, and X_s designate the thicknesses of the roof, the exterior wall, and the overhead basement slab respectively. Interior partitions are to be ignored here. The factor M is the "Mutual shielding factor" and for an isolated building has the values 0.85 for roof FPG and ASG, 0.58 for roof N, and 0.5 for walls. The factor B is the Barrier Factor and is a function of the thickness, X, of the specific barrier under consideration. The factor G is called Geometry Factor, and may itself be the difference and product of secondary "geometry factors." The geometry factors may involve barrier thicknesses in certain circumstances but are mainly a function of a so-called "solid angle fraction." A solid angle fraction is the fraction of a complete sphere subtended by the part of the structure under consideration. The solid angle fraction subtended by the roof from the central point in the basement is called "ω_u" for omega upper; that subtended by the basement ceiling alsb, "ω_ℓ", for omega lower. Another solid angle fraction, ω_e, will be used in accounting for neutrons scattered back to the detector point in the basement from the basement floor. One further quantity is used to describe the geometry of the building, the angle $\emptyset_o$, which is the angle between the perpendicular from the central detector point to the wall and a horizontal line to the corner of the building.

Using the above symbols, equation (1) for the reduction factor for the fission product gamma radiation impinging on the roof of a one-story structure and penetrating through the overhead basement slab to the detector point becomes:

$$RF_{RFPG} = 0.85 * B_{FPG}(X_r+X_s) * G_{FPG}(\omega_u, X_r+X_s) \quad (2)$$

Similarly, for the air secondary gamma radiation,

$$RF_{RASG} = 0.85 * B_{ASG}(X_r+X_s) * G_{ASG}(\omega_u, X_r+X_s) \quad (3)$$

For the neutrons and the related gamma radiation produced in their interaction with the various parts of the structure, it is necessary to include an estimate of the neutrons and their induced gamma rays scattered from the surfaces of the chamber, i.e., walls and floor. It is convenient to introduce an intermediate step. Define a quantity MBG as,

$$MBG_{RN} = 0.65 * B_{RN}(X_r+X_s) * G_{RN}(\omega_u, X_r+X_s) \qquad (4)$$

To account for the neutrons that scatter to the detector point, a quantity that depends on ω_ℓ and ω_e is added to equation (4) as,

$$RF_{RN} = MBG_{RN} * (1+\rho(\omega_\ell)+\rho_e(\omega_e)) \qquad (5)$$

Since a fraction of the neutrons that are captured in the structure lead to gamma rays, the scattered neutrons are accompanied by a smaller gamma ray component. A factor of 0.3 is used to evaluate this gamma ray component in the following:

$$RF_{NGAM} = 0.58 * B_{RG}(X_r+X_s) * G_{RG}(X_r+X_s) + 0.3 * (\rho(\omega_\ell)+\rho_e(\omega_e)) *(MBG_{RN}) \qquad (6)$$

To calculate the reduction factors for radiation penetrating the walls of the first story and then the basement overhead slab, one uses a straight forward approach for the FPG and the ASG components for each wall separately and treats the attenuation in the overhead basement slab as a multiplicative factor. However, for the N and the NGAM components of the RFs, the overhead slab is considered to be folded up against each of the walls. Again, the effect of neutron scattering must be corrected for.

For the FPG component the equation for the wall RF is,

$$RF_{WFPG} = 0.5 * B_{FPG}(X_e) * 0.85 * (G_{1FPG}(X_e,\omega_u) - G_{1FPG}(X_e\omega_\ell)) * G_{2FPG}(X_e, \text{Sin } \emptyset_o) * B_{FPG}(X_s) \qquad (7)$$

where the values of the Bs and Gs are taken from curves for wall cases. The expression for ASG is the same as Equation (7) with the values for ASG substituted for those of the FPG.

For neutrons penetrating a first floor wall and then the slab (but with the convention that the slab is folded up against the wall) and again defining an intermediate quantity, MBG_{WN} as,

$$MGB_{WN} = 0.5 * B_{WN}(X_e+X_s) * 0.58 * (G_{1WN}(X,\omega_u) - G_{1WN}(X,\omega_\ell)) *G_{2WN}(X, \text{Sin } \emptyset_o) \qquad (8)$$

and then,

$$RF_{WN} = MBG_{WN} * (1 + \rho(\omega_\ell) + \rho_e(\omega_e)) \qquad (9)$$

For the gamma radiation resulting from the capture of neutrons in the walls and floor of the basement one has an equation similar to Equation (6) for the roof case. For NGAM, for each wall,

$$RF_{NGAM} = 0.5 * B_{WG}(X_e+X_s) * 0.58 * (G_{1WG}(X_e+X_s,\omega_u) - G_{1WG}(X_e+X_s,\omega_\ell)) * G_{2WG}(X_e+X_s, \text{Sin } \emptyset_o) + 0.3 (\rho(\omega_\ell) + \rho_e(\omega_e)) * (MBG_{WN}) \qquad (10)$$

Example: This schematization was applied to the case of a one-story building with basement. The plan dimensions of the building were 100 feet by 100 feet. The basement was 10 feet deep with the detector position in the center and 3 feet above the floor. The first story was 8 feet high with light walls (X_e=7psf) and a roof having X_r=36psf (approximately equivalent to 3 inches of concrete). For this case: ω_u=0.739; ω_ℓ=0.875; ω_e= 0.946; $\emptyset_o$=0.707; $\rho(\omega_\ell)$=0.385; $\rho_e(\omega_e)$=0.655 and $\rho+\rho_e$=1.040. The overhead basement slab thicknesses chosen were: 12 inches, 14 inches, 16 inches, 18 inches and 24 inches. The corresponding mass thicknesses (Xs) were: 144 psf; 168 psf, 192 psf, 216 psf and 288 psf respectively.

Table A.1 gives values of the parameters occurring in Equations 1-10. Those parameters depending only on the geometry of the building have a constant value for all values of X_s. Two of the geometry factors G_{FPG} and G_{ASG}, while depending on ω_u, have values of 1.0 for ω_u=0.739 for all values of (X_s+X_r)>72 psf, and are thus constant for this example.

Table A.2 (a to e) presents the results for each of the five overhead basement slab thicknesses. The first section of the table for each thickness gives the reduction factors, separately for each radiation component and for roof (R) and wall (W), e.g., RR(FPG) is the roof reduction factor for fission product gamma radiation.

The four succeeding sections for each thickness apply these reduction factors to find the total inside dose DOSE(IN) for each of four weapon burst conditions. Since the relative proportion of fission product gamma radiation, air secondary gamma radiation and neutron radiation (plus its accompanying NGAM) change with weapon size and distance from the burst to a given overpressure value, the inside doses must be calculated for each condition. Shown are the DOSE(IN) for a 1 MT and a 200 KT weapon each at distances for which the overpressure values are 20 psi and 30 psi.

These values have been plotted for both weapon sizes and both overpressures. (See Figure 3.1 in the text.) The inside doses range from about 1000R for the 200 KT burst at 30 psi for a 12 inch overhead slab to about 5R for the 1 MT burst at 20 psi and a 24 inch slab. For the cases of 1 MT at 30 psi and 200 KT at 20 psi the curves are reasonably close together and show that to keep the inside dose less than 100 R an overhead slab thickness of between 14½ and 17½ inches of concrete would be required.

TABLE A.1

DATA SHEET - INITIAL NUCLEAR RADIATION STRUCTURE SHIELDING

QUANTITY		12" $X_s=144$ $X_r+X_s=180$ $X_e+X_s=151$	14" $X_s=168$ $X_r+X_s=204$ $X_e+X_s=175$	16" $X_s=192$ $X_r+X_s=228$ $X_e+X_s=199$	18" $X_s=216$ $X_r+X_s=252$ $X_e+X_s=223$	24" $X_s=288$ $X_r+X_s=324$ $X_e+X_s=295$
$B_{FPG}(X_r+X_s)$		0.0098	0.00580	0.00373	0.0024	0.00120
$G_{FPG}(\omega_u,X_r+X_s)$	*	1.0	→	→	→	→
$B_{ASG}(X_r+X_s)$		0.0275	0.018	0.012	0.0080	0.0025
$G_{ASG}(\omega_u,X_r+X_s)$	*	1.0	→	→	→	→
$B_{RN}(X_r+X_s)$		0.022	0.014	0.0091	0.0058	0.00155
$G_{RN}(\omega_u)$	*	0.86	→	→	→	→
$(\rho+\rho_E)$	*	1.040	→	→	→	→
$B_{RG}(X_r+X_s)$		0.0305	0.0245	0.0185	0.0128	0.0043
$G_{RG}(\omega_u,X_r+X_s)$		0.878	0.882	0.900	0.910	0.932
$B_{FPG}(X_e)$	*	0.62	→	→	→	→
$B_{ASG}(X_e)$	*	0.85	→	→	→	→
$B_{FPG}(X_s)$		0.020	0.010	0.0070	0.00380	0.00105
$B_{ASG}(X_s)$		0.056	0.044	0.031	0.022	0.0071
$G_{1FPG}(X_e,\omega_u)$	*	0.265	→	→	→	→
$G_{1FPG}(X_e,\omega_\ell)$	*	0.122	→	→	→	→
$G_{2FPG}(X_e,\text{Sin }\emptyset_o)$	*	0.54	→	→	→	→
$G_{1ASG}(X_e,\omega_u)$	*	0.167	→	→	→	→
$G_{1ASG}(X_e,\omega_\ell)$	*	0.063	→	→	→	→
$G_{2ASG}(X_e,\text{Sin }\emptyset_o)$	*	0.54	→	→	→	→
$B_{WN}(X_e+X_s)$		0.033	0.0205	0.013	0.0082	0.0021
$G_{1WN}(\omega_u)$	*	0.312	→	→	→	→
$G_{1WN}(\omega_\ell)$	*	0.155	→	→	→	→
$G_{2WN}(\quad\text{Sin }\emptyset_o)$	*	0.655	→	→	→	→
$B_{WG}(X_e+X_s)$		0.034	0.0270	0.0210	0.0165	0.0063
$G_{1WG}(X_e+X_s,\omega_u)$		0.291	0.300	0.310	0.318	0.344
$G_{1WG}(X_e+X_s,\omega_\ell)$		0.138	0.140	0.142	0.144	0.188
$G_{2WG}(X_e+X_s,\text{ Sin }\emptyset_o)$		0.622	0.640	0.642	0.650	0.680

*Quantities having same value for all values of $144\le X_s\le 288$psf.

TABLE A.2 (a)

INR REDUCTION FACTORS AND INSIDE DOSES

12 IN SLAB X_s=144

RR(FPG) = 0.00833		RF(FPG) = 0.00995	
RW(FPG) = 0.00162		RF(ASG) = 0.02791	
RR(ASG) = 0.02337		RF(N) = 0.03041	
RW(ASG) = 0.00454		RF(NGAM) = 0.02676	
RR(N) = 0.02238			
RW(N) = 0.00803			
RR(NGAM) = 0.01895			
RW(NGAM) = 0.00781			

Y=1MT @ 20 psi		Y=200KT @ 20 psi	
DR(FPG)	30.61	DR(FPG)	63.70
DW(FPG)	5.98	DW(FPG)	12.44
DT(FPG)	36.59	DT(FPG)	76.15
DR(ASG)	4.90	DR(ASG)	46.75
DW(ASG)	0.95	DW(ASG)	9.08
DT(ASG)	5.86	DT(ASG)	55.83
DR(N)	1.90	DR(N)	59.32
DW(N)	0.68	DW(N)	21.28
DT(N)	2.58	DT(N)	80.60
DR(NGAM)	1.61	DR(NGAM)	50.23
DW(NGAM)	0.66	DW(NGAM)	20.70
DT(NGAM)	2.27	DT(NGAM)	70.93
DOSE(IN)	47.31	DOSE(IN)	283.53

Y=1MT @ 30 psi		Y=200KT @ 30 psi	
DR(FPG)	81.16	DR(FPG)	167.59
DW(FPG)	15.86	DW(FPG)	32.75
DT(FPG)	97.02	DT(FPG)	200.35
DR(ASG)	23.37	DR(ASG)	144.92
DW(ASG)	4.54	DW(ASG)	28.17
DT(ASG)	27.91	DT(ASG)	173.10
DR(N)	16.11	DR(N)	235.05
DW(N)	5.78	DW(N)	84.32
DT(N)	21.89	DT(N)	319.37
DR(NGAM)	13.64	DR(NGAM)	199.03
DW(NGAM)	5.62	DW(NGAM)	82.04
DT(NGAM)	19.27	DT(NGAM)	281.07
DOSE(IN)	166.12	DOSE(IN)	973.90

TABLE A.2 (b)

INR REDUCTION FACTORS AND INSIDE DOSES

14 IN SLAB X_s=168

RR(FPG)	=	0.00493	RF(FPG)	=	0.00574
RW(FPG)	=	0.00081	RF(ASG)	=	0.01887
RR(ASG)	=	0.01530	RF(N)	=	0.01923
RW(ASG)	=	0.00357	RF(NGAM)	=	0.02131
RR(N)	=	0.01424			
RW(N)	=	0.00498			
RR(NGAM)	=	0.01471			
RW(NGAM)	=	0.00660			

Y=1MT @ 20 psi			Y=200KT @ 20 psi		
DR(FPG)	=	18.11	DR(FPG)	=	37.70
DW(FPG)	=	2.99	DW(FPG)	=	6.22
DT(FPG)	=	21.10	DT(FPG)	=	43.92
DR(ASG)	=	3.21	DR(ASG)	= =	30.60
DW(ASG)	=	0.74	DW(ASG)	=	7.14
DT(ASG)	=	3.96	DT(ASG)	=	37.74
DR(N)	=	1.21	DR(N)	=	37.75
DW(N)	=	0.42	DW(N)	=	13.21
DT(N)	=	1.63	DT(N)	=	50.97
DR(NGAM)	=	1.25	DR(NGAM)	=	38.98
DW(NGAM)	=	0.56	DW(NGAM)	=	17.50
DT(NGAM)	=	1.81	DT(NGAM)	=	56.49
DOSE(IN)	=	28.51	DOSE(IN)	=	189.13

Y=1MT @ 30 psi			Y=200KT @ 30 psi		
DR(FPG)	=	48.18	DR(FPG)	=	99.19
DW(FPG)	=	7.95	DW(FPG)	=	16.37
DT(FPG)	=	56.14	DT(FPG)	=	115.56
DR(ASG)	=	15.30	DR(ASG)	=	94.86
DW(ASG)	=	3.57	DW(ASG)	=	22.13
DT(ASG)	=	18.87	DT(ASG)	=	116.99
DR(N)	=	10.25	DR(N)	=	149.58
DW(N)	=	3.59	DW(N)	=	52.38
DT(N)	=	13.84	DT(N)	=	201.96
DR(NGAM)	=	10.59	DR(NGAM)	=	154.47
DW(NGAM)	=	4.75	DW(NGAM)	=	69.35
DT(NGAM)	=	15.34	DT(NGAM)	=	223.82
DOSE(IN)	=	104.20	DOSE(IN)	=	658.35

TABLE A.2 (c)

INR REDUCTION FACTORS AND INSIDE DOSES

16 IN SLAB X_s=192 psi

RR(FPG)	=	0.00317	RF(FPG)	=	0.00374
RW(FPG)	=	0.00056	RF(ASG)	=	0.01271
RR(ASG)	=	0.01020	RF(N)N	=	0.01242
RW(ASG)	=	0.00251	RF(NGAM)	=	0.01644
RR(N)	=	0.00925			
RW(N)	=	0.00316			
RR(NGAM)	=	0.01107			
RW(NGAM)	=	0.00537			

Y=1MT @ 20 psi			Y=200KT @ 20 psi		
DR(FPG)	=	11.65	DR(FPG)	=	24.24
DW(FPG)	=	2.09	DW(FPG)	=	4.35
DT(FPG)	=	13.74	DT(FPG)	=	28.60
DR(ASG)	=	2.14	DR(ASG)	=	20.40
DW(ASG)	=	0.52	DW(ASG)	=	5.03
DT(ASG)	=	2.67	DT(ASG)	=	25.43
DR(N)	=	0.78	DR(N)	=	25.53
DW(N)	=	0.26	DW(N)	=	8.38
DT(N)	=	1.05	DT(N)	=	32.92
DR(NGAM)	=	0.94	DR(NGAM)	=	29.34
DW(NGAM)	=	0.45	DW(NGAM)	=	14.24
DT(NGAM)	=	1.39	DT(NGAM)	=	43.58
DOSE(IN)	=	18.86	DOSE(IN)	=	130.54

Y=1MT @ 30 psi			Y=200KT @ 30 psi		
DR(FPG)	=	30.89	DR(FPG)	=	63.79
DW(FPG)	=	5.55	DW(FPG)	=	11.46
DT(FPG)	=	36.44	DT(FPG)	=	75.25
DR(ASG)	=	10.20	DR(ASG)	=	63.24
DW(ASG)	=	2.51	DW(ASG)	=	15.59
DT(ASG)	=	12.71	DT(ASG)	=	78.83
DR(N)	=	6.66	DR(N)	=	97.22
DW(N)	=	2.27	DW(N)	=	33.21
DT(N)	=	8.94	DT(N)	=	130.44
DR(NGAM)	=	7.97	DR(NGAM)	=	116.26
DW(NGAM)	=	3.87	DW(NGAM)	=	56.44
DT(NGAM)	=	11.84	DT(NGAM)	=	172.71
DOSE(IN)	=	69.94	DOSE(IN)	=	457.24

TABLE 2.A (d)

INR REDUCTION FACTORS AND INSIDE DOSES

18 IN SLAB X_s=216 psi

RR(FPG) = 0.00204		RF(FPG) = 0.00234	
RW(FPG) = 0.00030		RF(ASG) = 0.00858	
RR(ASG) = 0.00680		RF(N) = 0.00789	
RW(ASG) = 0.00178		RF(NGAM) = 0.01206	
RR(N) = 0.00590			
RW(N) = 0.00199			
RR(NGAM) = 0.00765			
RW(NGAM) = 0.00440			

Y=1MT @ 20 psi		Y=200KT @ 20 psi	
DR(FPG)	7.49	DR(FPG)	15.60
DW(FPG)	1.13	DW(FPG)	2.36
DT(FPG)	8.63	DT(FPG)	17.96
DR(ASG)	1.42	DR(ASG)	13.60
DW(ASG)	0.37	DW(ASG)	3.57
DT(ASG)	1.80	DT(ASG)	17.17
DR(N)	0.50	DR(N)	15.63
DW(N)	0.16	DW(N)	5.28
DT(N)	0.67	DT(N)	20.92
DR(NGAM)	0.65	DR(NGAM)	20.29
DW(NGAM)	0.37	DW(NGAM)	11.67
DT(NGAM)	1.02	DT(NGAM)	31.97
DOSE(IN)	12.13	DOSE(IN)	88.03

Y=1MT @ 30 psi		Y=200KT @ 30 psi	
DR(FPG)	19.87	DR(FPG)	41.04
DW(FPG)	3.01	DW(FPG)	6.22
DT(FPG)	22.89	DT(FPG)	47.26
DR(ASG)	6.80	DR(ASG)	42.16
DW(ASG)	1.78	DW(ASG)	11.06
DT(ASG)	8.58	DT(ASG)	53.22
DR(N)	4.24	DR(N)	61.96
DW(N)	1.43	DW(N)	20.95
DT(N)	5.68	DT(N)	82.92
DR(NGAM)	5.51	DR(NGAM)	80.41
DW(NGAM)	3.17	DW(NGAM)	46.26
DT(NGAM)	8.68	DT(NGAM)	126.67
DOSE(IN)	45.84	DOSE(IN)	310.09

TABLE 2.A (e)

INR REDUCTION FACTORS AND INSIDE DOSES

24 IN SLAB X_s=288 psi

RR(FPG)	=	0.00102
RW(FPG)	=	0.00008
RR(ASG)	=	0.00212
RW(ASG)	=	0.00057
RR(N)	=	0.00157
RW(N)	=	0.00051
RR(NGAM)	=	0.00256
RW(NGAM)	=	0.00157

RF(FPG)	=	0.00110
RF(ASG	=	0.00270
RF(N)	=	0.00208
RF(NGAM)	=	0.00413

Y=1MT @ 20 psi

DR(FPG)	=	3.74
DW(FPG)	=	0.31
DT(FPG)	=	4.06
DR(ASG)	=	0.44
DW(ASG)	=	0.12
DT(ASG)	=	0.56
DR(N)	=	0.13
DW(N)	=	0.04
DT(N)	=	0.17
DR(NGAM)	=	0.21
DW(NGAM)	=	0.13
DT(NGAM)	=	0.35
DOSE(IN)	=	5.15

Y=200KT @ 20 psi

DR(FPG)	=	7.80
DW(FPG)	=	0.65
DT(FPG)	=	8.45
DR(ASG)	=	4.25
DW(ASG)	=	1.15
DT(ASG)	=	5.40
DR(N)	=	4.17
DW(N)	=	1.35
DT(N)	=	5.53
DR(NGAM)	=	6.79
DW(NGAM)	=	4.16
DT(NGAM)	=	10.95
DOSE(IN)	=	30.35

Y=1MT @ 30 psi

DR(FPG)	=	9.93
DW(FPG)	=	0.83
DT(FPG)	=	10.77
DR(ASG)	=	2.12
DW(ASG)	=	0.57
DT(ASG)	=	2.70
DR(N)	=	1.13
DW(N)	=	0.36
DT(N)	=	1.50
DR(NGAM)	=	1.84
DW(NGAM)	=	1.13
DT(NGAM)	=	2.97
DOSE(IN)	=	17.95

Y=200KT @ 30 psi

DR(FPG)	=	20.52
DW(FPG)	=	1.71
DT(FPG)	=	22.24
DR(ASG)	=	13.17
DW(ASG)	=	3.57
DT(ASG)	=	16.74
DR(N)	=	16.56
DW(N)	=	5.36
DT(N)	=	21.92
DR(NGAM)	=	26.93
DW(NGAM	=	16.48
DT(NGAM)	=	43.42
DOSE(IN)	=	104.33

APPENDIX B

STANDARDS FOR PUBLIC SHELTERS

FOREWORD

Presented herein are standards relating to the design and construction of public shelters and shelters in hospitals. Explanations and background discussions relating to various provisions contained in the standards are included in this foreword.

These standards are intended to serve as guides for the design and construction of facilities that provide protection from the effects of nuclear explosions. The standards may be applied to new or existing facilities in both the public and private sectors. If the standards are to be a part of the requirements for buildings, then they must be adopted as a part of the local or State building codes.

A standard establishes criteria to measure, test, compare, or judge characteristics of building design and construction, such as capacity, quantity, context, extent, value, quality, durability, and capability.

The purpose of a building code is to safeguard the life, health, and general welfare of all occupants of a building and those near the building. The term building code means collectively all laws regulating the design and construction of a building, including all auxiliary components such as electrical wiring, mechanical equipment, and plumbing.

A building code contains a number of standards which cover the various materials, systems, assemblies, and design procedures that are allowed. Generally, a standard is included in a building code either as a part of its text or by reference, and thereby becomes a part of the code.

A worthy objective is that these standards for shelters become part of the nationally recognized model building codes, as well as local and State-adopted building codes. To that purpose, the standards are presented in a format that will permit the model code organizations and local and State governments to include them in their codes through adoption by reference.

The provisions of these standards address only those aspects of building design and construction that are unique to providing habitable space protected from the effects of nuclear weapons. Design and construction aspects of a conventional nature must comply with the provisions of local or State-adopted building codes.

The standards presented herein are minimum and do not preclude the designer from exceeding the requirements, except as may cause non-compliance with other requirements for the space that may be prescribed in other applicable codes.

The Federal Emergency Management Agency (FEMA) is charged with safe-guarding the Nation's resources of life, property, and industry from enemy attack and other wartime hazards as well as peacetime manmade and natural hazards that also create potential risks to the population, industry, and general economy of the Nation. FEMA is pursuing an integrated approach to mitigation, protection, response and recovery from a wide spectrum of hazards. The shelter standards presented herein are just one component--albeit an important one--among the several components of an Integrated Emergency Management System.

STANDARDS

Purpose

Section 1.1. The purpose of these standards is to establish minimum criteria for application to the design, construction, or designation of a space in a building or other facility as (a) a shelter to resist all nuclear weapon effects, (b) a shelter against fallout radiation only, and (c) shelter in hospitals.

Scope

Section 2.0. The scope of these standards extends to buildings, spaces, or other facilities designated for use as public shelters or hospital shelters.

Section 2.1 These standards establish technical, architectural, and environmental criteria for public shelters and hospital shelters.

Section 2.2. Some criteria in these standards apply equally to all-effects shelter, to fallout shelter, and to either type of shelter in hospitals. Where criteria differ, they are specified for each type.

General

Section 3.0 The standards furnish minimum criteria that provide for the protection of occupants from anticipated weapons effects in spaces whose habitability and environmental characteristics are governed by the emergency situation, the essential lifesaving purpose of the shelter, and the need to maintain austere medical care in hospital shelters.

Section 3.1. The standards indicate objectives to be met in the design and designation of shelters in new and existing buildings.

Section 3.2 These standards are minimum standards. Nothing contained herein shall be construed to preclude exceeding the criteria for any shelter, except as may cause non-compliance with other requirements for the shelter space that may be prescribed in local building codes.

Definitions

Section 4.0. The following definitions shall apply to all portions of these standards:

ALL-EFFECTS SHELTER is any room, structure, or space designated as such and providing its occupants with (1) fallout protection at a minimum protection factor of 100; (2) structural integrity under a design blast overpressure of 30 psi from a 1 MT surface burst; (3) protection against initial nuclear radiation (INR) so as to limit exposure to 200 rem from the INR at 30 psi blast overpressure for a 1 MT surface burst; (4) protection against a thermal pulse of 1200 cal/cm^2.

BLAST OVERPRESSURE is the sharp increase in air pressure in the shock wave produced by a nuclear explosion.

DUAL-USE SHELTER is a space having a normal, routine use and occupancy as well as an emergency use as a shelter.

EFFECTIVE TEMPERATURE is an empirical index that combines in a single number the effects of temperature, humidity, and air movement on the sensation of heat and cold felt by the human body.

ELECTROMAGNETIC PULSE (EMP) is the sharp spike of long wavelength electromagnetic radiation produced by a nuclear explosion. Although not injurious to people, EMP can damage unprotected electrical and electronic equipment.

FALLOUT SHELTER is any room, structure, or space designated as such and providing its occupants with protection at a minimum protection factor of 100 from fallout radiation resulting from a nuclear explosion.

INITIAL NUCLEAR RADIATION (INR) is the radiation emitted from the nuclear explosive reaction and the resulting residue within the first minute after a nuclear explosion. It consists of neutrons and gamma rays emitted almost instanteously as well as gamma rays emitted by the fission products in the rising cloud.

MEGATON is the size of a nuclear explosion equivalent to that of one million tons of TNT.

PROTECTION FACTOR (PF) is a numerical value that expresses the relation between the amount of fallout radiation that would be received in a protected location and the amount that would be received if unprotected.

SINGLE-PURPOSE SHELTER is a space having no use or occupancy except as a shelter.

UNIT OF EGRESS WIDTH is 22 inches.

<u>Occupancy</u>

Section 5.0. General. Nothing in this standard shall be construed as preventing the dual use or multiple use of normal occupancy space as all-effects or fallout shelter, providing the minimum requirements of each are met.

Section 5.1. Mixed Occupancy. The occupancy classification shall be determined by the normal use of a building or space. When a normal-use space is designed to have an emergency use as a shelter in addition to the normal use, the most restrictive requirements for all such uses shall be met.

Section 5.2. Occupancy Separation. That portion of a building or other facility designed to provide all-effects shelter will be separated from the remainder of the structure by the presence of blast-resistant boundaries and doors that must be closed to achieve the protection. No occupancy separation is required between that portion of the space designed as fallout shelter and the remainder of the building. A plan indicating the fallout shelter space and its boundaries shall be furnished as a means of identifying the fallout shelter.

Section 5.3. Space. Space allowances for use as public shelter and hospital shelter shall be as follows:

(a) Floor Area. A minimum of 10 sq. ft. of net floor area per occupant shall be provided in public shelters. A minimum of 35 sq. ft. of net floor area, based on nominal bed capacity, shall be provided per patient in hospitals, reserved exclusively for patient use, as contrasted with staff or public use. A minimum of 15 sq. ft. of net floor area shall be provided per hospital staff member engaged in patient care. Staff space shall be separated from public shelter space by partitions or other physical barrier. Partitions, columns, areas occupied by moveable furniture or other materials within the shelter space, and areas used for storage of consumable shelter supplies may be included in net floor area. However, areas occuped by fixed equipment, such as emergency generators, may not be included in net area calculations.

(b) Head Room. A minimum head room of 6.5 feet shall be provided.

(c) Volume. A minimum of 65 cubic feet of net volume shall be provided per occupant in public shelters. New volume shall be determined using the net area calculated for the space.

Section 5.4 Period of Occupancy. Public and hospital shelters shall be designed to permit occupants to remain sheltered for a minimum of 14 days without egress.

Section 5.5. Number of Occupants. Shelter space shall be provided for at least the anticipated normal occupants or 10 percent of the volume of the structure, whichever is larger. In no case shall the shelter provide for less than 50 persons.

Protection

Section 6.0 General. The minimum level of protection for public and hospital fallout shelters shall be as prescribed in Section 6.1. The minimum level of protection for public and hospital all-effects shelters shall be as prescribed in Sections 6.1, 6.2, 6.3, and 6.4.

Section 6.1. Fallout Radiation. Protection from fallout radiation at a minimum protection factor (PF) of 100. Protection factors shall be calculated using methods approved by the Federal Emergency Management Agency based upon publication TR-20 (Volume 1) Shelter Design and Analysis - Fallout Radiation Shielding, June 1976 edition and TR-20 (Volume 2) Shelter Design and Analysis - Protection Factor Estimator With Instructions, February 1976 edition.

Section 6.2. Blast Overpressure. Structural integrity to resist a design overpressure of 30 psi from a 1 MT surface burst. Calculational methods for blast protection shall be based on TR-20 (Volume 4) Protective Construction, May 1977 or later edition. Closures shall have equivalent resistance.

Section 6.3. Initial Nuclear Radiation. The floor slab above the shelter area and any exposed wall areas shall be a minimum of 14 inches of reinforced concrete. Door and ventilation openings shall be baffled to provide equivalent protection. Other openings shall not constitute more than 0.01 percent of the net floor area.

Section 6.4 Thermal Radiation and Fire. Shelters designed in accordance with the criteria in Sections 6.2 and 6.3 are more than adequate to protect against the thermal pulse and transmission of heat from fires outside the shelter area. Ventilation closures prescribed in Section 7.5 shall be located to permit the shelter to be closed off temporarily in the event of the presence of combustion gases.

Ventilation and Temperature

Section 7.0. Ventilation. Ventilation of the shelter space shall comply with the standards contained in TR-20 (Volume 3), Shelter Environmental Support Systems, May 1978 edition, available from the Federal Emergency Management Agency.

Section 7.1. Fresh Air. A minimum of 3 cu. ft. of fresh air per minute per occupant shall be provided in public shelters to avoid oxygen depletion and carbon dioxide buildup. A minimum of 7 cu. ft. per minute per occupant shall be provided in hospital shelters.

Section 7.2. Effective Temperature. Public shelters shall have a ventilation rate sufficient to maintain a daily average effective temperature of not more than 82°F (28°C) with at least a 90 percent reliability of not exceeding that value during the year. Effective temperatures shall be determined using procedures contained in Handbook of Fundamentals, 1977 edition or later, prepared by the American Society of Heating, Refrigerating, and Air-Conditioning

Engineers, Inc. (ASHRAE). Zones of equal ventilation rates in cubic feet of air per minute that meet the requirements of this section are shown in Figure B.1. The ventilation rate in hospital shelters shall be sufficient to maintain a daily average effective temperature of not more than 70°F (21°C) with at least a 90-percent reliability of not exceeding that value during the year.

Section 7.3. Ventilation Systems. Ventilation systems for public and hospital shelters shall be designed to provide the prescribed fresh air and temperature conditions during periods when commercial electric power may not be available.

Section 7.4. Minimum Temperature. A temperature in hospital shelters of not less than 65°F (18°C) shall be maintained during the occupancy period. In public shelters, a temperature of not less than 50°F (10°C) shall be maintained during the occupancy period.

Section 7.5. Air Intake and Exhaust. In all shelters, the air intake openings shall be positioned not less than 2 feet above any surface on which radioactive fallout could be deposited and the opening shall be hooded or positioned to prevent deposits of radioactive fallout on the intake face. Additionally, in all-effects shelters, the exposed air intake and exhaust structures shall be designed to resist the blast overpressure and shall be fitted with closures capable of being closed both manually and by pressure-sensitive mechanism.

Section 7.6 Filters. Special filters are not required for ventilation of public shelters or hospital shelters other than those prescribed by other building regulations. Standard dust filters shall be provided if the face velocity across the outside air intake is greater than 150 feet per minute.

Section 7.7. Recirculated Air. Air shall not be recirculated from wards, treatment rooms, toilets or other areas that could contaminate the air supply in hospital shelters.

Lighting

Section 8.0. Public Shelters. Emergency lighting is required in public shelters to provide a minimum lighting level of 2 footcandles at the floor.

Section 8.1. Hospital Shelters. Lighting shall be provided in hospital shelters as prescribed below:

(a) A minimum lighting level of 100 footcandles in treatment rooms at treatment table height.

(b) A minimum lighting level of 25 footcandles at desk height in patient areas.

(c) A minimum lighting level of 2 footcandles at the floor in all other areas.

Emergency Electric Power Supply

Section 9.0. General. Standby emergency electric power is necessary to operate the emergency lighting and ventilation equipment for shelter occupants should commercial electric power not be available during shelter occupancy.

Section 9.1. Disconnects and Switching. Disconnecting devices and appropriate switching gear shall be provided to direct the emergency supply of power to the ventilation equipment and emergency lighting needed in the shelter area only.

Section 9.2. Fuel Supply. Emergency engine generators shall include a storage tank having a minimum fuel supply capacity sufficient for at least 14 days of continuous operation of the equipment. In all-effects shelters, the fuel storage tank and its piping to the emergency generator shall be designed to remain operable under the blast overpressure protection criterion.

Section 9.3. Shielding of Equipment. The emergency generator, together with its controls and distribution panels shall be located in an area having protection meeting the minimum standards for all-effects or fallout shelters. Access to the generator space also must meet the same protective criteria. All electrical equipment, including lighting circuits, shall be protected against the electromagnetic pulse (EMP) in accordance with the guidance contained in the current edition of FEMA's Electromagnetic Pulse Technical Manual.

Section 9.4. Power Outlets. Appropriate power outlets for emergency power circuits shall be provided in the shelter area to operate emergency ventilation equipment and lighting.

Section 9.5. Venting. Emergency engine generators shall have separate vents exhausting fumes outside the structure and shall be heat-isolated from areas used by shelter occupants. In all-effects shelters, equipment openings (e.g., outside air intakes, exhausts, or vents) shall be equipped with closures to prevent blast overpressures from entering the shelter area.

Section 9.6. Isolation. The emergency generator shall be isolated from the shelter area to minimize noise levels to the habitable area of the shelter. Toxic fumes and heat shall be vented to the outside.

Section 9.7. Ground shock. In all-effects shelters, the emergency generator shall be shock mounted. Electric and fuel conduits to the generator shall be flexible and shock isolated against ground movement.

Blast Doors (Applicable to All-Effects Shelter Only)

Section 10.0. All exterior entryways and exits must be protected by blast doors designed to withstand the requirements of this Standard. The attitude of the blast door may be in a horizontal plane, a vertical plane, or an inclined plane. Blast doors may be hinged or sliding.

Section 10.1. For blast doors with hinges, provision must be made for the relief of the hinges from the blast loading.

Section 10.2. Blast doors shall be designed to withstand rebound during the negative pressure phase of the blast loading by providing appropriate interior latches. Latches will be manual and operable from both sides.

Section 10.3 Blast doors shall be designed so that if plastic deformation takes place, it will not cause jamming of the door thereby preventing it from being opened or closed properly.

Section 10.4. The shelter walls housing the blast door shall be designed so that they will withstand door thrust loading and not fail prior to failure of the blast door.

Section 10.5. Blast doors, if hinged, shall be designed to open outward and be easily moved by one person.

Shock Mounting of Shelter Components (Applicable to All-Effects Shelter Only)

Section 11.0. All components, hardware, equipment, storage tanks, cabinets, toilets, ducts, pipes, brackets, etc., installed in or attached to the walls, ceilings or floors of the all-effects shelter area shall be mounted so as to be capable of withstanding the ground shock resulting from the design loading specified in Section 6.2 of this standard.

Section 11.1. Shock isolation for shelter occupants is not a design requirement.

Access and Egress

Section 12.0. Public shelters shall have no fewer than two widely separated means of access and egress leading to other spaces of the building or directly to the outdoors. In all-effects shelters, at least one means of egress shall be a tunnel to an emergency escape hatch located at least 40 feet from the structure.

Section 12.1. Means of access and egress for dual use shelter space shall meet the requirements prescribed by local building codes for normal, routine use of space.

Section 12.2. Means of access and egress for single purpose shelters shall aggregate at least one unit of egress width for every 200 shelter occupants. In no case shall a single opening be less than 24 inches wide.

Section 12.3. Emergency-type hatchways may be used as a means of access and egress, provided that at least one means of access and egress for the shelter is a standard opening conforming to the requirements of the local building code. Hatchways, if used, shall be a minimum size of 24 inches x 36 inches.

Section 12.4. One or more means of access and egress to a hospital shelter space shall be at least 40 inches wide to permit passage of hospital beds.

Structure Siting

Section 13.0. Structural design of the shelter area shall comply with these standards and local building codes.

Section 13.1. Shelters to resist all nuclear weapons effects shall be placed in basement areas only and not abovegrade. In building sites with high water table, subsurface rock or expansive soil conditions, all-effects shelters may be located on the lowest aboveground story provided the story is buried by architectural earth berms of compacted fill having a slope of one vertical to at least three horizontal.

Fire Resistance

Section 14.0. Shelters shall meet fire safety requirements as indicated below.

(a) Dual use shelters shall comply with requirements applicable for normal occupancy of the space.

(b) Single purpose shelters shall provide a flame-spread rating for interior surfaces not exceeding 200 on the flame spread scale and 450 or less on the smoke test scale when tested in accordance with ASTM E-84.

Hazards

Section 15.0. Hazardous utility lines, such as steam, gas, and oil lines, shall not be located in or near the shelter area unless provision is made to control such lines by valving or other means which permit shut-off of flow through the shelter area. Valving or other controls shall be readily accessible from the shelter area and shall conform with local mechanical and gas building codes.

Sanitation

Section 16.0. Chemical type toilets on the basis of one toilet per 50 shelter occupants shall be provided in the shelter area. (Normal flush type toilets are not likely to be operable during the emergency period because of inadequate water.)

Section 16.1. Dry chemicals and water will be used for charging the toilets each time they are emptied. A two week supply of chemicals and water (or other charging agent) will be required for storage in the shelter area. Sewage shall be ejected to a storage tank outside the shelter area.

Drinking Water

Section 17.0. Water containers (flexible or fixed shape) shall be provided capable of storing at least 7 gallons of potable water for each shelter occupant.

Section 17.1 The shelter area shall be equipped with stored water containers to be filled during an emergency period. One or more water outlets shall be located in the shelter area to facilitate filling of water containers.

Food and Other Supplies

Section 18.0. Consideration shall be given to locations for storage of food and medical supplies but provision of such supplies is not required.

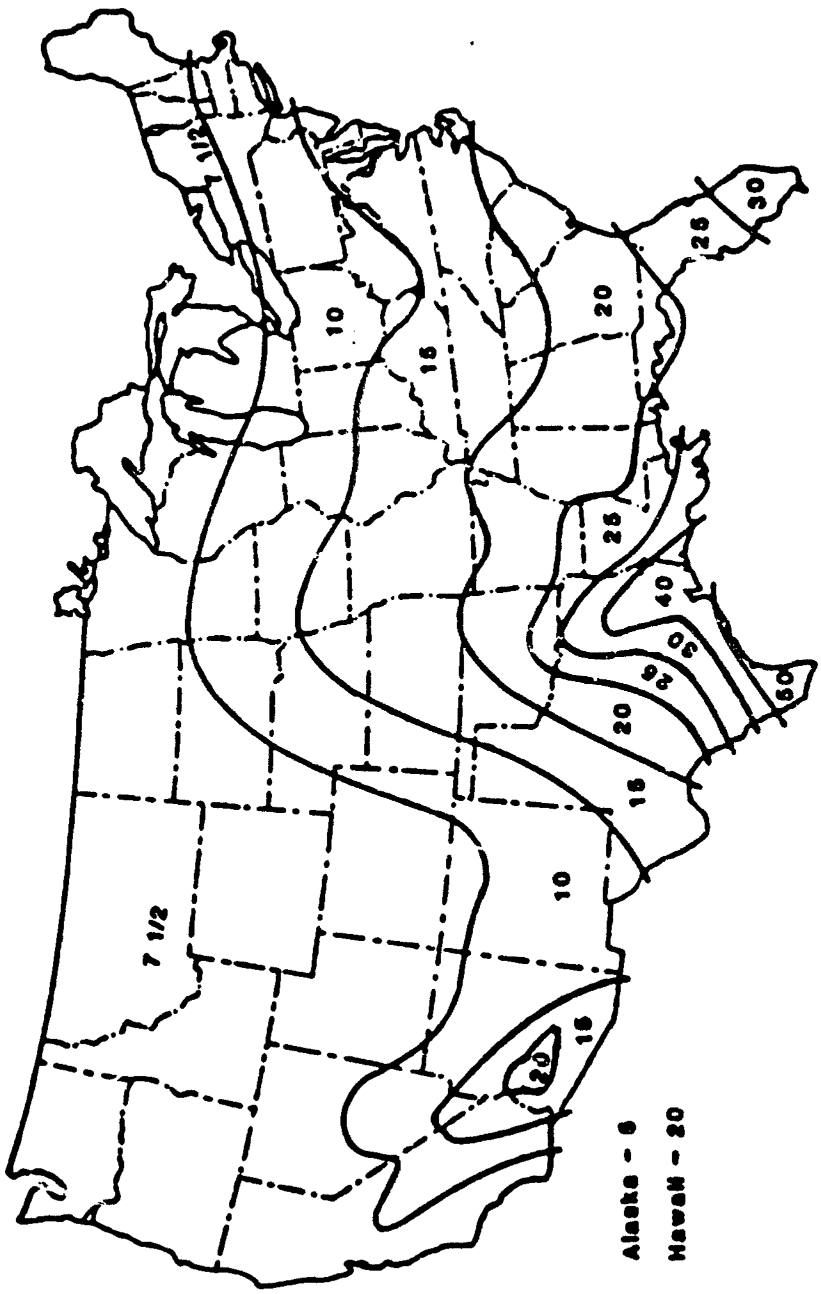

FIGURE B.1: ZONES OF EQUAL VENTILATION RATES (CFM per person)

APPENDIX C

ENGINEERING ASPECTS

By H. L. Murphy*

This appendix covers four engineering support tasks needed to provide the overall project with several items of specific information/data. The work is discussed below in summary terms.

UPDATING ESTIMATED COSTS
OF COMBINED EFFECTS SLANTING CASE STUDY BUILDINGS

The first task was the updating, through revised Engineering News-Record (EN-R) Indexes, of the case study costs in Chapter 8 of the basic/research Combined Nuclear Effects, or Full, Slanting guidance, Reference 3. The EN-R Building Cost Index (BCI) values for 9/83 and for 3/85 are 2430 and 2428 (1913=100), respectively. The 1913=100 values were used for calculations because they are the oldest ones in our work, and are larger values (than 1967=100) with which to work.

Using Table 8.0A, p. 8-69, and its Addendum, p. 8-70: the Table's "Jan. 68" line (BCI=692) of unit costs ($/sf) can be multiplied by the ratio 2428/692 or 3.50867052# to produce a new bottom line, Mar. 85, of estimated unit costs.[3] The same thing can be done to Tables 8.0D and E, p. 8-103 and -105, resulting in the following table, which shows Mar. 85 estimated unit costs for 15, 20, and 30 psi blast protective spaces.

It should be noted that the project study considers only closed shelters. Hence, only the cost data in the following table for buildings 2A, 3A with and without mezzanine, and 4A are reflected in Section III of the project report. Building 4A was conceived as an open shelter but the results of the second support task indicate little if any cost change for a closed version at 15 and 20 psi overpressure.

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(#) Decimal places are for calculational understanding, not to imply accuracy.

BUILDING	15 PSI	20 PSI	30 PSI	
2A (closed)	21.19	22.67	27.72	$/sf
2B (open part)	18.60	23.96		
" (closed part)	24.35	29.02		
" (total)	20.49	25.54		
2C (open)	27.51			
3A (closed)				
" w/mezzanine	17.37	18.74	23.09	
" no mezzanine	18.42	20.21	25.54	
4A (open)	17.12	19.40		

(Reference 3 has information on cost estimating on other pages: 6-19 thru 6-20A.9, 6-42, and many charts like (and following) the one on p. 6-45.)

ESTIMATED COST OF LIGHT-VEHICLE DOOR FOR UNDERGROUND PARKING GARAGE

The second support task was to prepare a preliminary estimate cost of a light-vehicle door for an underground parking garage. Bldg 4A from the slanting guidance in Reference 3 was selected for use, but with the stipulation that the door be a general one for the purpose, rather than one taking specific advantage of that particular building, e.g., of its many ramp turns as related to INR protection.

Door design weapons effects inputs: 14 in. thick reinforced concrete (R/C) (dictated for INR protection in any exposed horizontal or vertical surface, ignoring building superstructure as a shield); 1 MT (contact) surface burst; peak free-field overpressures, p_{so} = 15, 20, and 30 psi. These effects mean:

$p_m = p_r$ (peak reflected blast overpressure)[4,Eq.3.50.2; or 5,Eq.3.56.2]
t_o = 1.55, 1.38, and 1.15 sec. (positive phase duration)[3,p.2-2 Brode curves]
t_{oo} (calculated as needed)[6,p.3-44/5]

Door design parameters: Essentially a one-way R/C slab used as a wall section, with main rebars running horizontally and no loads in the slab plane, was selected for consideration. This eliminates the need for building supports at top and bottom of door, instead drawing support from vertical (door end) supports from building interior walls that must be strengthened to act as shear walls (or "inside" buttresses, to coin a usage) and carry all loads down to strengthened foundations.

t = 14 in. (door thickness)

d = 12.5 in.

d' = 1.5 in.

b = 1 in.

L = 120 in. (clear span)

P_u = 0 (neglecting door weight; negligible effect relative to total loads)

μ = 1 (Reference 3, p.6-84, para #1, lines 3-6)

p = 1% to 2% (usual upper and lower limits, for ductility, etc.)[3]

p' = p (for full rebound, and negative blast, protection)

$f_{dy} = 1.25\ f_y$ = 72,000 psi (ASTM A615, Grade 60 reinforcing steel)

E_s = 29,000,000 psi

$f'_{dc} = 1.25\ f'_c$ (for 3,000 and 5,000 psi concrete)

Entry parameters: Ramp width and doorway height, 12 ft and 10.5 ft, respectively, giving a door width of 12 ft (clear span 10 ft) and door height of 8 ft (clear height 7-1/3 to 7-1/2 ft).

Design procedure used was that for interior walls[3,p.G-53], Steps 1-7, 9, and 10. Step 5 is discussed briefly in the paragraph where "interior walls" is underlined; this design does indeed fall under Case 2 of Table 6.6 (p.6-88) because this case is for use where the (main) tension steel goes into the plastic range before the compression steel. Steps 6 and 9 use Eq.6-4, p.6-33. In Step 10, $p_m = p_r$ rather than p_{so}.

After one trial design (using calculator), a computer program was written, checked against the trial design and the first numerical example in Reference 3, then used to obtain the following design values:

p_{so}	15	20	30	psi
p_r	40.73	45.73	55.73	psi
t_{oo}	.7104	.6152	.5023	sec
For f'_c = 3,000 (beta$_1$ = 0.85):				
p	.0145	.0163	.0200	
For f'_c = 5.000 (beta$_1$ = 0.80):				
p	.0142	.0160	.0197	

Cost Estimate: Forms reused to use successive pours for the four doors; plywood sheets, treated, on ground; pours are essentially one-way slabs, lifted into place after 28 days; cost estimate items (per door) as follows:

				$/door	REF.7
Ready-mix concrete: 14" x 12' x 7'6" = 3.9 cy					
less rebars vol. = 3.8 cy @$51 & 57, use 54M(matls only)				$ 205	p.80
Forms, edge, 7"to 12"high, 4-use, on grade@$2.59/sf contact					p.71
area; for 14"use $3, incl.plywd, (2(7.5+12)(14/12)/4($3))				34	
Placing @$7.20/cy x 3.9 cy				28	p.85
Curing, say,				10	p.82
Finish, broom/trowel @$.40/sf (7.5 x 12)				36	"
SUBTOTAL, concrete				$ 313	
Reinf. stl:	15	20	30 psi		
Main rebars: 2A=2pbd=2p(7.5x12)12.5=2250p sq. in.					
Wt.=2250p/144(12)(490)=91875p lbs. (Use p's for 3000# conc., table above)					
	1332	1498	1838	(Lbs.@$995/ton; slab on grade #3 to #7)	p.77
(add 15%, temp&web)$	762	857	1052		
Xtra, web bending, say	100	100	100		
SUBTOTAL, reinf.stl$	862	957	1152		
Carriage&tracks (str.stl.) & Misc.					
Str.stl: 2 angles, 8"x6"x1", 44.2 plf ea.@12', 1061#/door[8]					p.1-42
2 " 6"x4"x7/8", 27.2 plf ea.@24', 1306 " "				"	"
Total stl: 2367# @($360+54(del'y)+26(paint)+10%O&P)/ton				$ 573	p.392
Wheels (Hillman Equip.Co., Inc., Flat-Top Rollers, Model 2-R, see Figure C.1)					
Capacity 3-3/4 tons ea.; 6 ea.@$137.20 =				823	
Misc. welding of angles, rebars, etc., say,				300	
Moving doors, say,				100	
SUBTOTAL, str.stl.& Misc.				$ 1796	

SUMMARY:	15	20	30 psi
Concrete subtotal $	313	313	313
Reinf.stl. "	862	957	1152
Str.stl.&misc. "	1796	1796	1796
TOTAL, $/door $	2971	3066	3261

Cost comparisons: Overly Doors quoted (8/84) $110,000 for a 9-ton door (approx. same as door above), frame, track, trolley, electric operation, freight and tax (to resist 1,000 psi dynamic, t_o = 0.4 msec.). A WES report[9] states that "Existing commercially available doors, capable of withstanding 50

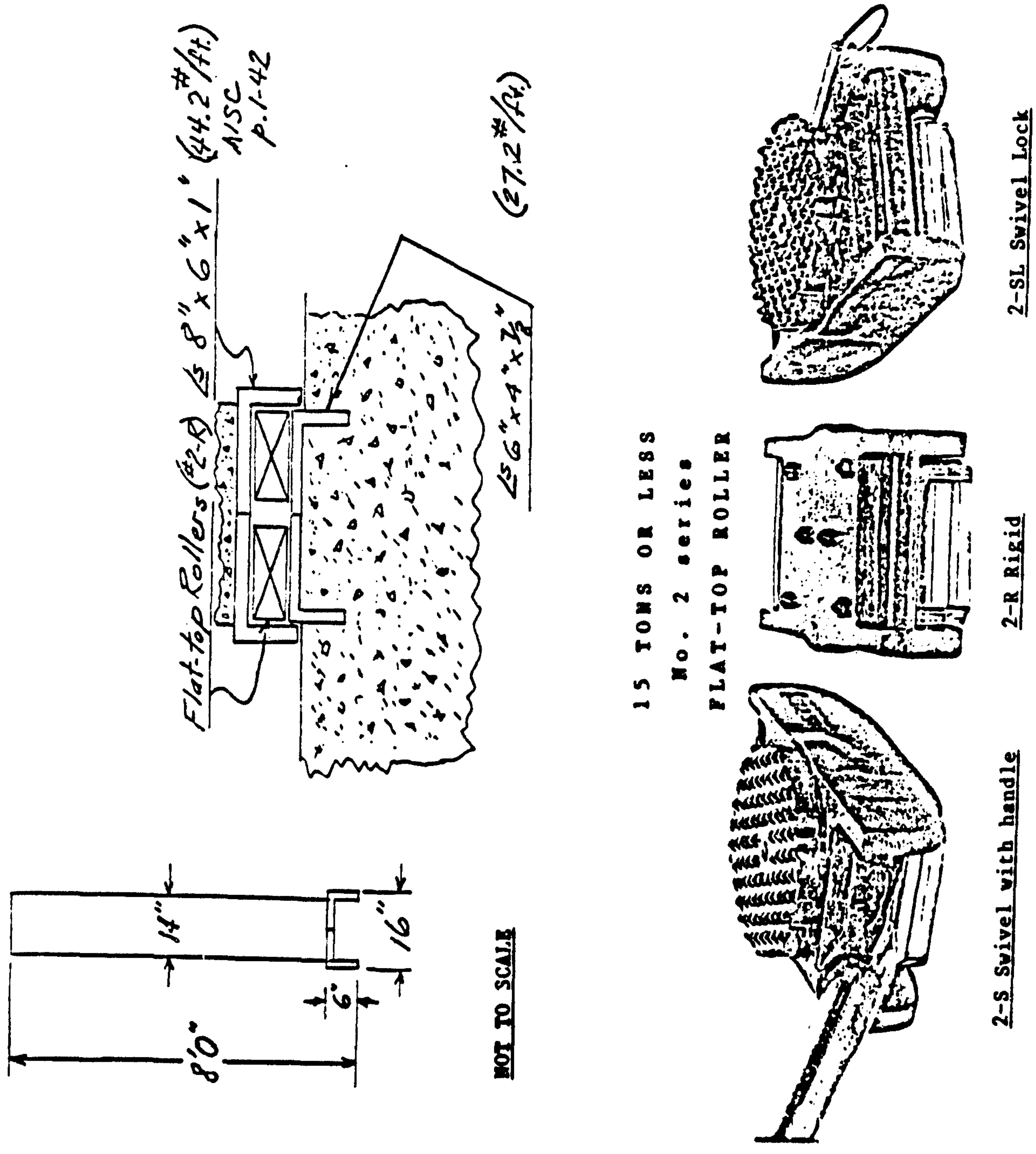

Figure C.1: FLAT-TOP ROLLERS

to 150 psi, range in price from about $5,000 to $51,000 each, while reinforced-concrete blast doors could be built for about $1,000 each, or $900 each if purchased in lots of 20 or more.". An Operation Plumbbob (1957) summary report[11] describes a R/C door, 4-1/2 ft thick, tested in an underground garage; cost recollection (not found in report summary), $60,000.

INR protection in doors: Not included above, in either design or costs section, is one low-cost item: Reference 14 revealed the need for neutron-gamma shielding using a combination of steel plate and Masonite (without the combination, the door shielding, for example, would require 14" thick steel to replace the 14" thick R/C because of differences in neutron shielding capability); thus, the 2" thick structural steel, in the channels supporting each door on its tracks, would have to be augmented by Masonite, and perhaps more sheet steel, to meet the additional INR shielding required; the materials needs are not yet calculated. Reference 18 may be useful in this matter.

Door concepts (re those designed and estimated above): Doors, and both indoor and outdoor ramps, should have many "pad-eyes" or "tie-downs" for use in moving/anchoring the doors; this work can be done by hand using a "Come-A-Long Pull/Hoist" (as in Sears Craftsman line) or "2-ton Power Winch Puller" (that "Power" is muscle power!). Each door should have, on the building, a 24-ft long channel (steel, or R/C equivalent) to anchor the top edge of each door against the (negative) blast wave; in the closed position, building clearance for the door should be such that some wood members, perhaps "2-by" thick, could be used to seal the door against blast entry by using the Come-A-Longs inside the building, one at each end of the door, to draw the door tight against the 2-by's.

Slanting cost increase factors: The wall behind each door in its open position would have to be full-slanted for p_r, not just p_{so}; more concrete and reinforcing steel would be needed. Ramp wing walls would have to be strengthened to serve as shear walls (mentioned earlier) to carry the door loadings down to additional foundation capacity; additional reinforcing steel would be needed, probably also more concrete. Nonetheless, it appears that costs of design changes to make Bldg 4A (or any similar large belowground parking facility) a closed shelter rather than an open one would be quite minor compared to the overall slanting costs shown in the tables on page C-2 for 15 and 20 psi design overpressures.

COMMENTS ON FULL SLANTING GUIDANCE FOR SMALL CLOSURES AND ON SURVIVABILITY OF VENTILATION SYSTEMS

The third task was to review existing slanting guidance,[3] then augment it as appropriate, on: (a) closures for small openings into a closed shelter; and, (b) survivability of ventilation systems.

Closures

One wood and two steel blast door schemes are introduced and illustrated by pages 8-2 (last sentence) and 8-7 (Fig. 8-0E), respectively, of Reference 3, which includes other pertinent items: Fig. 8-0E is discussed on page 8-109, where mention is also made of two stipulations pertinent to this summary, the first and sixth on page 1-3. Table 8.0G (page 8-110) gives considerable data on designs, blast-resistant capacity, and costs, for 10 steel doors (4 guillotine and 6 hinged) and 8 wood doors (hinged, metal-clad). Table 8-0G costs can be updated, at least approximately, from its costs at origin, June 1970 costs for San Francisco area, to March 1985 for the "20-cities average," both as used by EN-R; the multiplier is 2.833 (2428/857), using sources and data mentioned in the first task report above, relative to EN-R, etc.

Both steel door designs, guillotine and hinged, use steel plate and stiffeners (angles) for more economy in material than if heavier steel plate alone were used; however, if both MT and KT weapons must be considered, design in solid plate (augmented by Masonite or other wood) would be better (see paragraph "INR protection in doors: ..." in the preceding (second) task report).

Simplified design procedures for closure panels are available in Reference 10 for plywood (p.25 and App.A3), wood (p.26 and App.B1), and steel plate (p.27 and App.D1, especially pages D1-9 thru -13). The latter pages were used to prepare the table below. For guillotine (steel plate unreinforced) door costs, it is suggested that $50/sf (of opening) for 1/4" plate be used (deduct and add 20% for 1/8" and 3/8", respectively), which is intended to allow for the cost of the support area plate steel along the four edges, and for the generally smaller sizes than perhaps was contemplated in Table 8.0G (the author hastens to add that these cost figures are very rough, due to no project time, and should be researched, even a little, if used on any significant project overall costs).

Opening Clear Spans are L_1 and L_s; use latter on Fig. D1-1.

Steel Plate Thickness vs. p_{dm} (= p_{so}):

L_1/L_s =		1	1.5	2	>2 (used 2.2)		
Plate th.							
	Size:	6x6	6x9	6x12	6x13.2 in.		
1/8"		102	72	60	34	psi	(34.0)
	Size:	9x9	9x13.5	9x18	9x19.8		
1/8"		45	32	27	15		(15.0)
1/4"		>150	>106	>88	>50		(50+)
	Size:	12x12	12x18	12x24	12x26.4		
1/8"		26	18	15	9		(8.5)
1/4"		104	73	61	35		(34.5)
	Size:	18x18	18x27	18x36	18x39.6		
1/8"		12	8	7	4		(3.9)
1/4"		46	32	27	15		(15.3)
3/8"		104	73	61	35		(34.5)

The above table demonstrates use of one-way steel plate design values of p_{dm}, in the right side column (headed ">2"), as read directly from Fig. D1-1 for each of the plates short-side span: 6", 9", 12", and 18" (the "as-read" values, including interpolation efforts, are actually those shown in parentheses at the end of each row). From this column of p_{dm} values, all of the other values in the rows are calculated, using the factors (multipliers) for two-way plates, as shown on the lower half of page D1-10.[3] For example, using the first row of our table above, the right end figure, 34.0 psi, was multiplied by 3 (factor for L_1 / L_s = 1) to get the p_{dm} = 102 for a 6x6 plate.

Further, the above table is based on use of ASTM A7, A36, A373, or A529 carbon steel. Correction factors for High-Strength Steels are shown on p. D1-10.[3] For example, for ASTM A242 steel the correction factor is 1.149, meaning that for this steel all p_{dm} values in the table above would be multiplied by 1.149 (or would be increased by 14.9%).

Ventilation Systems Survivability

An excellent briefing for discussing this subject is contained in Reference 3, Appendix H.1 (by F. C. Allen), pages H.1-11 and -12. The subject is extremely important as related to normal-use building design, because ventilation ducts use large openings through the cover slab over the basement, thereby adversely affecting basement use as a protective shelter. The air blast overpressure levels contemplated under this project are such that the floor above the shelter would be swept clear of everything, including ventilation ducts, and the air blast would then penetrate the shelter space through the vent duct openings.

Like so many matters in combined nuclear effects slanting of a new basement, shelter requirements that are thought of at the building's design stage can be met less expensively than by later upgrading of the building. Emergency power supply, at least part of it, should be located on the basement level, and protected, not necessarily by an enclosed space but perhaps in a nearby steel-grating-covered box structure with top at grade (high survivability of such protection was demonstrated in a nuclear field test. Operation Plumbbob, Priscilla Shot, 1957). Basement ventilation must start with protected air intakes/exhausts, which can come from emergency exit/fresh air intake or exhaust structures, such as considered for Building 4A of Reference 3, p. 8-89 thru -91; estimated costs are shown in Table 8.4A, p. 8-81&2, items 5-7. Air supply ducts can be run along a basement wall (preferably a long-side wall) to sweep fresh air across the shelter into exhaust ducts on the opposite wall. Both intake and exhaust ducts require blast closures, as discussed above, either automatically- or hand-closed.

For the ventilation ducts penetrating the shelter cover slab, such closures are also required. The following discussion assumes use of vent ducts that are rectangular in cross-section, as they are usually. One method would be to provide a closure on the top of the cover slab, with the duct opening properly strengthened to take the blast closure device, and with the closure's air blast load transmitted to the cover slab and further support structure system. A steel plate closure fabricated to slide along the floor surface, as illustrated[3] for a vertical closure on the guillotine door of p.8-7 might be used, but such an arrangement is likely to be clumsy, and takes up floor area alongside the vent duct. If the vent duct and opening is built a little oversize, with enough room inside for a steel plate closure door, the door can be hinged to one of the long-side steel angles that frames the vent duct opening. A little space (on the hinge side) is needed to have the steel plate lean slightly against the inside of the vent duct, thus using gravity to hold the blast closure in a normally-open position. Manual closure would be by pulling a light chain running from the top edge of the blast closure, downward and to the opposite side of the vent, exiting into the basement shelter space, from which the closure would be pulled to horizontal, being held closed by several heavy catches welded to the steel angle frame supporting the blast closure. A vent duct inspection slide should be located above the cover slab, on the side opposite the blast closure door hinges; the inspection slide would serve its obvious maintenance/inspection purpose, as well as for reopening the closed blast door. Design of the steel plate blast closure is as discussed above; design in wood or plywood is no more difficult, but steel plate is probably the better material for such use.

In summary, it's best to reduce, or eliminate, openings in the basement cover slab, e.g., have elevators located on the outer face of the building and entry stairs likewise. But if this is unacceptable to the building's normal-use, resort must be had to blast closure devices. For the latter, manual operation is urged, both for lower costs and for dependability over time with little or no maintenance needed; automatic closures are expensive both originally and to maintain (if that gets done at all).

COMMENTS ON EXISTING COMBINED EFFECTS SLANTING GUIDANCE RESOURCE MATERIAL[3]

The final support task was to prepare comments on the existing combined nuclear effects slanting guidance[3] resource material in terms of its adequacy, currency, and shortcomings, including recommendations for its improvement and general revision. The following comments apply to Reference 3 unless otherwise indicated:

Problem Areas might be restated as follows:

R/C is best material, considering strength and shielding, but worst to upgrade in such things as support system for beam/slab cover over basement shelter, under present design procedures, that is.

Present Slanting approach has these shortcomings:

Too conservative - in terms of estimated blast resistance level;
Too costly - in both design and construction;
Too few things deferable - beyond original construction;
Too difficult to strengthen to a higher blast protection level;
Provides no probability distribution of blast protection level;
Too expensive to train civil/structural engineers in design use;
(Lacks public understanding, even in technical circles.)

Above summary of the problem areas was adapted from References 12 and 13, specifically from a section on "Problems With Present Slanting Approach" of Reference 12 (unpublished, copyrighted, used with permission).

A remedy is offered for all of the above Full Slanting shortcomings: that remedy is to spend some research effort in developing the new design approach described in References 12 and 13, which were written to propose a modest annual expenditure for research with concurrent physical testing over a period of years, just as was done in the past work that resulted in Reference 3. The result of even the first increment of the needed research would be to strongly impact the above shortcomings, that is:

Reduce conservatism and construction cost;

Allow more deferable original construction by making future strengthening possible for most applications, at least easier for others, to meet either original design blast levels or higher blast levels;

Eliminate the need for special courses for engineers preparing protective designs, at least for the principal structural components that require most of the design time and special training (e.g., learning dynamic design, which is design for time-varying loads: specifically, peak loads applied instantaneously then decaying rapidly to negative loads then to zero loads - solving equations of motion, single-degree-of-freedom problems, etc.)

Provide answers that include probability distributions sufficient for use in national attack studies, projected cost studies, etc.

The percentage value of improvements would increase as the assumed blast levels increase.

Other specific areas in Reference 3 needing attention are as follows, geared to that source:

CHAPTER 1

1. Update chapter, especially the Scope, p. 1-2

CHAPTER 2

2. Chapter's charts are sufficiently accurate for structural design and other purposes with one exception: Reference 14 pointed out that the Initial Nuclear Radiation (INR) charts, neutron and combined neutron-gamma, may be slightly on the non-conservative side, based on interim results revealed by an

ongoing FEMA research project that is developing an INR Shelter Analysis procedure, to parallel the long-available FSA (Fallout Shelter Analysis) engineering method and its later simplifications. Check against Reference 5 should be made.

CHAPTER 3

3. No known shortcomings, but the short chapter should be reviewed by civil defense fire researchers, on FEMA staff or contractor (e.g., Stan Martin).

CHAPTER 4

4. Update chapter to agree with current civil defense planning; e.g., the INR protective requirements, if ET weapons are contemplated, will control R/C building design, rather than air blast protection, in many cases, more as the weapon yield goes lower (a minimum thickness of, say, 14 in. for exterior walls/exposed floor slabs may apply, at blast levels of 15 to 30 psi, to meet INR requirements).

CHAPTER 5

5. No updating needed.

CHAPTER 6

6. Comments 1, 2, and 4 above affect this chapter. Many changes should be made in this chapter to update it, and the chapter will be heavily affected by accomplishing the needed structural engineering research pointed out above and in References 12 and 13. Other comments dealing with portions of this chapter follow.

7. Table 6.4, p. 6-14, needs current steels added to it by cross-reference to p. 6-26.

8. Diagonal tension design, especially allowable stresses, is in the chapter's first full design procedure on p. 6-37, item 10, and is an item of all R/C design procedures in Reference 3. Updating of this design aspect will probably be rather simple, but should certainly be checked. For example, Reference 15 has a 1985 update In Press; this update is understood[16] to have been based on the latest ACI Code[17] coverage of Shear (which now includes diagonal tension) and Seismic Provisions (App. A), adapted to nuclear protective structures needs.

9. R/C design charts for one-way slabs, of which there are many in Reference 3 starting with one on p. 6-44, will have to be expanded in coverage,

per comments 6 and perhaps 7 and/or 8 above, as well as having the existing ones corrected if found necessary under comment 8.

10. R/C estimating charts for one-way slabs (weight and thickness) (starting with one on p. 6-45) need correction/expansion paralleling comment 9.

11. Re comments 9 and 10: Chart revisions may be necessary to accommodate design (strength and INR) against KT yield weapons, especially as yields go lower (all R/C design/estimating charts of Reference 3 are for 1 MT yields or higher).

12. Re comments 9 and 10: Accomplishment of the structural design research recommended[12,13] would make comments 9 and 10 inapplicable.

13. Wood beam design, in this chapter and later in Reference 3, as well as in Reference 10, should be checked for needed corrections if effects of lower KT weapons must be considered. Same comment applies to other wood design (plywood and stressed-skin plywood panels) in References 3 and 10.

14. Steel plate design is subject to the same comments as in 13.

15. R/C design of two-way and flat slabs (p. 6-135 and -144) is subject to most of the above comments relating to one-way slabs.

CHAPTERS 7 & 8

16. No updating needed; a comment will cover the fact that older design procedures were used to size structural members, but that the effect on costs is believed to be small, i.e., less than the inaccuracy inherent in extending old estimates by using cost indexes. The illustrative value of the design studies will be undiminished.

CHAPTER 9

17. Shortcomings unknown; need for updating/expansion should be determined by an EMP expert's review (working with a structural dynamics engineer).

CHAPTER 10

18. This Summary chapter will need updating as changes are made pursuant to the above comments.

CHAPTER 11

19. The Further Work comments should be considered, and revised if any further research work is done on Combined Nuclear Effects Slanting.

20. All further pages of the chapter furnish data fundamental to structural dynamics design methods and need no changes.

APPENDICES

21. Data in the appendices will be generally subject to the above comments relating to each one's subject area in the main text. Project time for further study of the appendices was unavailable.

GENERAL

22. Review should be made of AIA (American Institute of Architects) design work done under FEMA contract in recent years: For application/usefulness of (Combined Nuclear Effects) Slanting guidance[3,10,15]; for possible over-design by checking the AIA designs against ESE (Existing Structures Evaluation) techniques developed for FEMA over the years; and, for recommendations for changes in both Slanting and ESE areas.

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(*) Now SRI International, Menlo Park, CA 94025
(#) Now U.S. Federal Emergency Management Agency, Washington, D.C. 20472
(%) Publications with AD- numbers are available from NTIS, Springfield, VA 22151
(**) Now U.S. Dept. of Energy

13. A Proprietary Proposal for Research (uses same title as Reference 12), Proposal No. 8303, submitted by James E. Beck & Associates on May 10, 1984, to the Federal Emergency Management Agency, Acquisition Management Division, Policy and Support Branch, Washington, D. C. 20472. NOTE: Part I.A of this proposal is the copyrighted paper that is Reference 12 above.

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17. Building Code Requirements for Reinforced Concrete (ACI 318-83), American Concrete Institute, Box 19150, Redford Station, Detroit, Michigan 48219.

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(#) Now U.S. Federal Emergency Management Agency, Washington, D.C. 20472

APPENDIX D

DRAFT SHELTER LEGISLATION

The draft legislation below is couched as an amendment to the Federal Civil Defense Act of 1950, as amended (50 U.S.C. App. 2251 et seq.). The amendment adds two sections to Title II of the Act. The first section mandates shelter in Federal buildings. The second offers a flat incentive payment to all other owners.

SHELTER IN FEDERAL STRUCTURES

"Section 208. (a) Public shelter shall be incorporated in all structures to be constructed in the future and owned or occupied by any department or agency of the United States whether civilian or military, unless exempted from such shelter requirement in accordance with the procedures and criteria prescribed pursuant to subsection (b). Such shelter shall afford protection against peacetime hazards and all appropriate nuclear weapons effects for at least the normal occupants of the structure, 50 people, or in ten percent of the structure's floor area, whichever is greater.

(b) The President may prescribe rules and regulations to carry out the provisions of subsection (a). Such rules and regulations shall make provisions for the establishment of procedures and criteria for incorporating appropriate public shelter in new buildings and other structures. Regulations establishing exemptions shall be limited to the following bases for such exemptions:

(1) The total floor area of the building, alteration, modification or other structure is less than 5,000 square feet;

(2) The building is a residence containing less than five dwelling units unless part of a larger residential development project;

(3) The new construction is a residential development project or subdivision containing less than twenty dwelling units;

(4) The proposed shelter would be in areas where additional public shelter space is not required;

(5) The proposed structure would house hazardous materials or processes that would make the incorporation of public shelter unwarranted or impractical;

(6) The proposed incorporation of public shelter would seriously impair the operational use of the structure and such use is required in an emergency;

(7) The characteristics of a structure other than a building (e.g., bridge, pipeline, tower) make the incorporation of public shelter impractical;

(8) The structure will be located in a flood plain or storm surge area as defined by the Federal Insurance Administration.

"(c) A statement that the incorporation of shelter into any new structure to be constructed has met the requirements of subsection (a) shall be submitted to the Congress as a part of the authorization procedures for new structures which may be required by other provisions of law.

"(d) There is hereby authorized to be appropriated annually not to exceed $_______________ to carry out the purposes of this section, to remain available until expended.

SHELTER FINANCING

"Section 209. (a) The Administrator is authorized to make payments on the basis of approved applications to States, to their political subdivisions, or to instrumentalities of either, or to private institutions and individuals which create public shelter in their new facilities. Such public shelter must meet standards and criteria therefor, established under the provisions of this Act and must be available to the public, without limitation, in event of threat of attack or other hazard, in accordance with local shelter use plans.

"(b) Payments made under subsection (A) shall be made at a flat rate as follows:

(1) For all-effects shelter, $30.00 per square foot of available space;

(2) For fallout shelter, $6.00 per square foot of available space:

these rates to be indexed yearly to reflect changes in construction costs..

"(c) There is hereby authorized to be appropriated annually not to exceed $____________ to carry out the purposes of this section."

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Center for Planning and Research, Inc.

Contract: EMW-84-C-1570 September 1985

Shelter incentive programs of the past are reviewed and eleven candidate programs constructed for encouraging the incorporation of multi-hazard shelter in basements of new buildings. Projections of new construction and incentive behavior are made, leading to a preferred program design based on a flat incentive payment scheme.

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