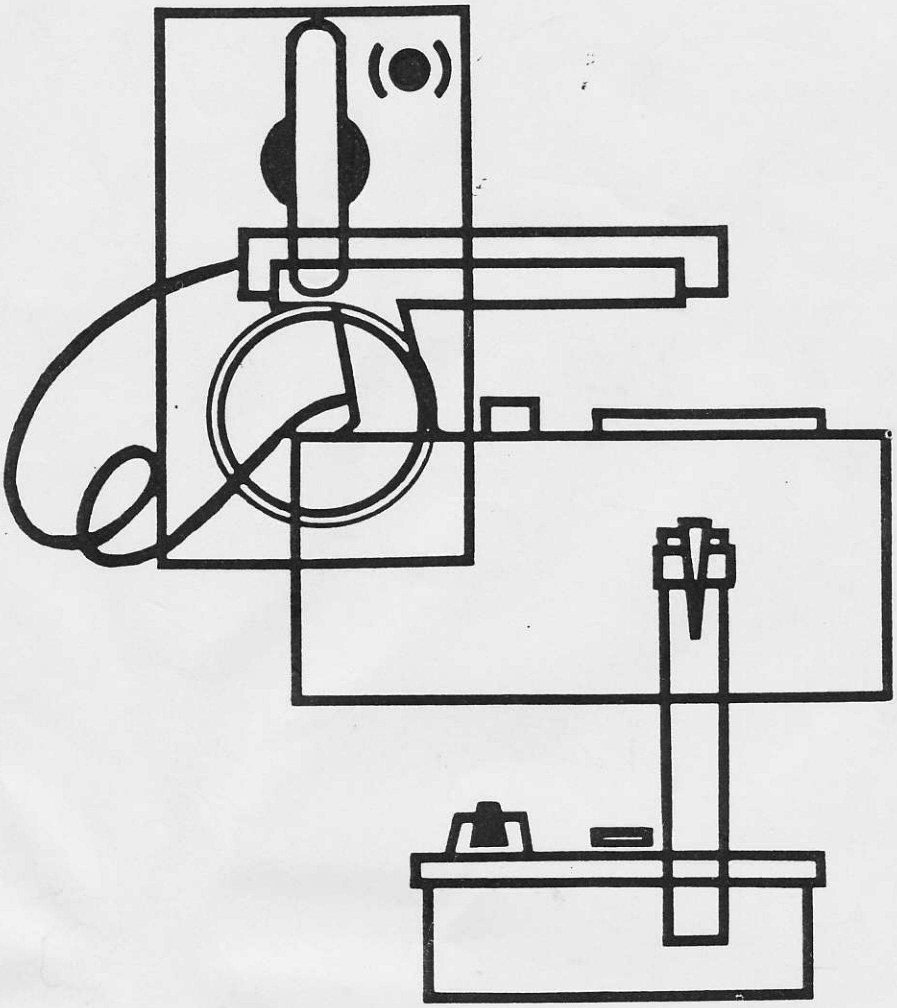
FEDERAL EMERGENCY MANAGEMENT AGENCY CPG 3-1 / September 1986

Radiological Instruments: An Essential Resource for National Preparedness



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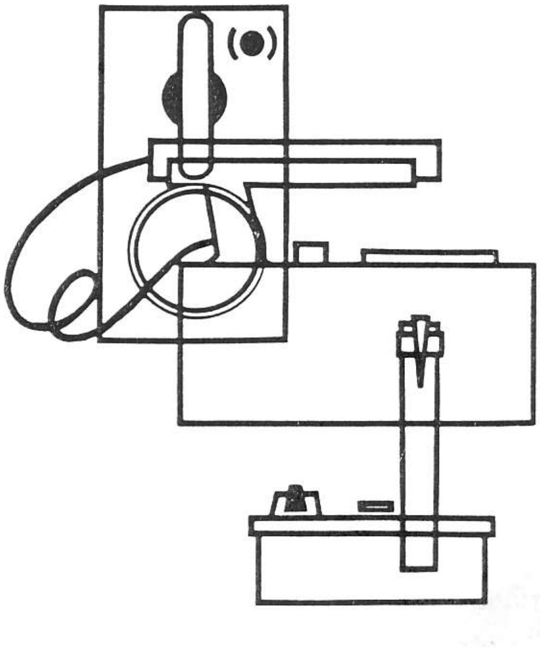

September 5, 1986 CPG 3-1

RADIOLOGICAL INSTRUMENTS:

AN ESSENTIAL RESOURCE FOR NATIONAL PREPAREDNESS

Federal Emergency Management Agency
Washington, D.C.
August 1986

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Civil Preparedness Guide

Federal Emergency Management Agency
Washington, D.C. 20472
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EXECUTIVE SUMMARY

This Civil Preparedness Guide (CPG) establishes and documents the need for procurement and nationwide distribution of radiological defense (RADEF) instruments in sufficient quantities to protect the population and to make recovery activities possible in the event of a large-scale nuclear disaster. It describes established State and local systems for storing, maintaining, and using these instruments. It also projects instrument quantities required to meet national needs for radiological defense. The following paragraphs highlight the major points of the report.

Events involving nuclear materials or weapons and resulting in a hazardous radiological environment are possible. Hence, under the Federal Civil Defense Act of 1950, as amended, the Federal Emergency Management Agency (FEMA) is charged with developing plans and procedures for national population protection and for providing radiological instruments to support population protection during and after a nuclear attack. In keeping with the intent of this legislation, the report emphasizes nuclear attack preparedness measures involving radiological instruments.

Experience has shown that emergency response and recovery efforts are hampered--even nullified--when emergency preparedness activities are neglected. To do all that is humanly possible to protect the population of the U.S. in the event of a nuclear disaster, radiological preparedness activities must begin now.

Studies have shown that millions of people might survive the direct effects of even a massive nuclear strike. Radiological instruments are the "eyes" that would permit survivors to "see" an otherwise invisible threat to their health: fallout radiation. Without such instruments, members of a post attack society would be unable to sense the hazard around them and, hence, unable to take protective measures that could greatly increase their chances of survival.

In the event of a nuclear attack, short lead-time commercial production of instruments would not be feasible. Survivors would need immediate access to appropriate, working radiological instruments. The Federal Government has granted a sizeable inventory of instruments distributed among State and local governments. However, these instruments were manufactured in the 1960's, and overall quantities fall far short of national needs. An opportunity currently exists to correct this shortfall while taking advantage of recent technological advances in instrument design and engineering.

The need for specialized radiological instruments for national civil defense was recognized in the early 1950's. Today, the natiowide inventory consists of over 4.3 million radiological instruments. In the 1960's, 5.7 million instruments were procured at a cost of over $53 million. In 1962, a 100 percent Federally funded program to support proper instrument maintenance and calibration by the States was initiated. Today, 152 full-time State personnel annually inspect and calibrate one-quarter of the instruments in the national inventory. The instruments are processed in specially equipped State shop facilities.

FEMA's leadership in instrument procurement and distribution is supported by special facilities, other Federal Agencies, and private contractors. Since 1965, FEMA's Emergency Management Systems Test Facility has conducted instrument performance testing and has provided guidance to the State personnel. U.S. Department of Energy laboratories have been active participants in the instrument program, as have the National Bureau of Standards and the U.S. Army and Navy. Recently, the William Langer Jewel Bearing Plant, Rolla, North Dakota, has been involved in the pilot production phase of low-cost radiological instruments. This will result in specifications that will allow private plants to produce cost-effective, high-quality instruments.

FEMA also assists State and local governments in developing radiological defense programs at the community level where first-response activities would take place. If a nuclear event occurred, planning and training at the local level would make millions of Radiological Response Team members, first responders, and critical workers available nationwide to implement response and recovery activities. However, their efforts would be severely limited without immediate access to appropriate quantities of radiological instruments.

FEMA recognizes eight generic functional areas in developing capabilities to manage emergency preparedness and response. Activities could not be performed in a hazardous radioactive environment without an adequate supply of radiological instruments at the State and local levels. Radiological instrument support is a requirement to augment and reinforce these eight generic capabilities and to develop a nuclear attack response and recovery capability.

Across the U.S. today, State and local operational areas number 3,450. This is the minimum number of government units that must have fully developed emergency management capabilities—including a multihazard radiological emergency response capability--to achieve the goals of a nationwide IEMS. Within these operational areas, users and facilities requiring radiological instruments include:

- Over 100,000 Radiological Response Team members.
- Nearly three million emergency services personnel.
- Over 20 million critical workers.
- Fixed and mobile emergency operating centers numbering 3,450 each.
- Key broadcast facilities numbering 2,700.
- Approximately 740,000 public shelter facilities.
- 20,000 key worker shelter facilities.

These are the major categories of personnel and supporting facilities that would be used to protect the public and to direct and implement response and recovery efforts in the event of a nuclear disaster. However, estimates show that for the five most essential types of radiological instruments, the current national inventory does not meet even 30 percent of projected national requirements in the best case. In the worst case, the current national inventory meets only a scant one percent of the projected requirement. Thus, current shortfalls in the five most essential types of radiological defense instruments range between 71 and 99 percent.

With respect to radiological instrument needs for this country in preparation for the possibility of a nuclear attack, it is obvious that total numbers of instruments required depend on plans for using them. In the case of shelter instruments, requirements depend on factors such as whether or not plans are to provide equipment for shelter spaces in high hazard areas, and if so, whether instruments would be issued to shelterees, pre-located in the shelter spaces, available to accompany evacuees (thus affecting requirements in reception areas), and the like. Currently, only a portion of the necessary State and local plans have been completed. Therefore, quantities of radiological instruments required as stated in this document represent best estimates of minimum requirements, in the absence of these plans.

Nationwide, there is a requirement for 68,482,700 radiological instruments. The chart, Summary of Radiological Defense Instrument Requirements, on the following page categorizes instrument requirements by functions and user categories.

Samuel W. Speck

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Associate Director
State and Local Programs and Support

SUMMARY OF RADIOLOGICAL DEFENSE INSTRUMENT REQUIREMENTS

Functions and User Categories	High-Range Dosimeters	Intermediate-Range Dosimeters	Low-Range Dosimeters	Chargers	Wide-Range Ratemeters
● Direction and Control/Continuity of Government					
- Fixed/Mobile EOC (.003 million facilities)	51,750	51,750		41,400	41,400
- Broadcast Facilities (.003 million facilities)	5,400	5,400		5,400	5,400
● Attack Response/Multihazard Application					
- Emergency Services Personnel (2.805 million)	(2,805,014)	(2,805,014)		(561,000)	(561,000)
- RRT Members (.107 million)	(103,500)	(103,500)		(103,500)	(103,500)
● Population Protection/Public and Key Worker Shelters					
- Key Worker Shelters (.030 million facilities	170,000	170,000		40,000	40,000
- Public Shelters (.739 million facilities)	29,190,000	29,190,000		2,919,000	2,919,000
● Postattack/Incident Recovery Operations					
- Critical/Key Workers (19.782 million)	(19,782,000)	(19,782,000)		1,643,400	1,643,400
- Emergency Services Personnel (2.805 million)					
● Training	(210,000)	(210,000)	350,000	(35,000)	(105,000)
Total Net Requirement	29,417,150 (100%)	29,417,150 (100%)	350,000 (100%)	4,649,200 (100%)	4,649,200 (100%)
Current Inventory*	2,562,005 (9%)	227,863 (1%)	102,439 (29%)	412,236 (8%)	636,000 (14%)
Current Shortfalls	**26,855,145 (91%)**	**29,189,287 (99%)**	**247,561 (71%)**	**4,236,964 (92%)**	**4,013,200 (86%)**

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* All these instruments will require eventual replacement. Training instruments have a high rate of attrition, and some have inherent technical problems that cannot be fixed. In addition, the inventory does not reflect other special purpose instruments for aerial radiological monitoring, source sets for training, special EOC and government preparedness equipment, and equipment for maintenance and calibration of the inventory.

FOREWORD

A hazardous radioactive environment could result from a range of potential events.

- Nuclear detonation within the United States:
    - Unsophisticated terrorist activity (possibly one fission weapon of a few kilotons).
    - Sophisticated terrorist activity (possibly a thermonuclear weapon or two or more fission weapons).
    - Accidental detonation of U.S. nuclear weapons.
    - Accidental launch from another country of nuclear weapons targeted to missile silos or other military installations in the United States.
    - Accidental launch from another country of nuclear weapons targeted to urban areas of the United States.
    - Full-scale nuclear attack against the United States.
- No nuclear detonation within the United States:
    - Fallout from ground bursts of nuclear weapons in other countries involved in a nuclear war.
    - Fallout from nuclear testing in other countries.
    - Sabotage or other deliberate actions leading to contamination of areas external to facilities that produce or use radioactive materials.
    - Accidental contamination of areas external to facilities that produce or use radioactive materials, including power reactor accidents.
    - Sabotage or other deliberate action to power reactors leading to the release of radioactive materials into the environment.
    - Accidents involving mobile reactors (such as satellite, ship, or submarine reactors).
    - Transportation accidents involving the spill of radioactive materials.

Given that these radiological events are possible, the Federal Emergency Management Agency (FEMA) is required by Congress under Title V, Improved Civil Defense Program:

> to the extent practicable, to develop and implement an improved civil defense program which includes—
>
> (1) A program structure for the resources to be used for attack-related civil defense.
>
> (2) A program structure for the resources to be used for disaster-related civil defense; and
>
> (3) Criteria and procedures under which those resources planned for attack-related civil defense and those planned for disaster-related civil defense can be used interchangeably.

In terms of radiological instruments, this requires consideration of the total spectrum of potential radiological events. This spectrum is illustrated in the Radiation Incident/Environment Matrix on the next page taken from "The Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack," proceedings of a symposium sponsored by the National Council on Radiation Protection and Measurements, page 261. However, the primary goal of FEMA's efforts must be to provide instruments for the possibility of nuclear attack (Federal Civil Defense Act of 1950, as amended). In the matrix, information in the second column under "WEAPON ATTACK, Multiweapon" indicates that the major instrument requirements are for the nuclear attack contingency. Therefore, emphasis in this document is placed on nuclear attack.

If, as a nation, we believe that the probability of a nuclear attack or terrorist detonation of a nuclear weapon is sufficiently real that it should not be ignored and if we hope to apply the technical knowledge developed through years of research that would enable us to protect against the widespread radioactive fallout that would result, **then now is the time to plan and to acquire the requisite equipment.** If we wait until such an event occurs or even until it seems imminent, it will be too late.

The purpose of this document is to:

(1) Explain why special instruments are needed.

(2) Outline the scope of the radiological threat.

(3) Discuss the consequences of radiation exposures.

(4) Summarize the history and current status of the radiological instrument procurement program.

(5) Explain the instrument maintenance and calibration program.

(6) Summarize the status of research and development activities.

RADIATION INCIDENT/ENVIRONMENT MATRIX

ENVIRONMENT \ INCIDENT	WEAPON ATTACK		POWER REACTOR ACCIDENT		TRANSPORTATION ACCIDENT		TRANS-OCEANIC FALLOUT
	Multiweapon	**Single Weapon 1-40 kt**	**Core Melt**	**No Melt**	**Surface Transport—Spent Fuel Rods**	**Air Transport—Weapons**	
Exent of contamination	Millions of square miles. Major segments heavily contaminated. Most of the rest lightly affected.	Few square miles heavily contaminated. Larger areas lightly affected.	Uncontaminated core melt: up to a few square miles of heavy contamination. Up to a few hundred square miles lightly affected. Contained core melt: very light contamination for up to a few hundred square miles.	Same as core melt with lower consequences.	One to a few hundred square miles.	-1 square mile	Rainy areas during fallout cloud passage.
Population Exposure	Up to 100 million fatalities. Essentially entire population exposed to some radiation.	Prompt Casualties 2,000 to 110,000 depending on yield (1 to 40 kt)[1] -10^6 persons exposed to radiation from fallout (1 kt)	Up to two million persons. Very few to LD/50 or greater dose.	Same as core melt with lower consequences.	Zero to a few thousand persons exposed.[2] Few, if any, to LD/50 or greater dose.	1 to 1000 persons exposed.[3] Few, if any, to LD/50 or greater dose.	Potential exposure of hundreds of thousands of persons to low-level doses.
DOSIMETRY Requirements	B-Y survey meters, dosimeters, chargers.	Same as multiweapon plus low intensity gamma survey meters (and/or alpha survey meters), air samplers, airborne gamma spectrometer with low intensity sensors and computing capability.	Same as single weapon.	Same as single weapon.	Same as single weapon.	Low intensity gamma survey meters and/or alpha survey meters.	Airborne gross-beta activity measurement capability. Beta-gamma survey meters.
Available Instruments	Requirements exceed available supply by factor of 5 to 10.	Probably adequate, but rapid relocation probably would be required.	Adequate.	Adequate.	Adequate quantities, but rapid movement would be required for most locations.	Adequate.	Adequate.

[1] Optimum ground zero for 40 kt over Detroit.
[2] Assuming population density from 0 to 1 per sq. km.
[3] Assuming population density from 0 to 1000 sq. mi.

(7) Define a proposed Federal program for procuring the required instruments.

(8) Provide specific procurement milestones.

(9) Provide a focus for critical decisions that must be made about radiological instruments.

Chapter 1

THE NEED FOR SPECIAL INSTRUMENTS

Soon after the discovery of X-rays (by Wilhelm Roentgen in 1895) and of radium (by Pierre and Marie Curie in 1898), people working with X-rays and radium began to learn about the dangers associated with them. Many of the early radiologists suffered severe damage to their fingers and hands, but it was many years before the so-called stochastic effects (cancer and genetic damage) were identified. One reason for the delay in recognizing the dangers of radiation was the inability of the people involved to sense the presence of the radiation or to judge its intensity. As everyone who has had a dental or chest X-ray knows, there is no physical sensation associated with the exposure.

Commercial sources of radiation measuring instruments were slow to develop. The instruments were difficult to design and build and the market was quite limited. Before World War II, only one or two commercial suppliers existed. When the Manhattan Project (the U.S. effort to build an atomic bomb during WW II) got underway, the need for large numbers of instruments became apparent. But because of the lack of a commercial supply and because of security requirements, scientists mostly had to produce their own.

After the war, the Atomic Energy Commission (the civilian agency established by Congress to take over the U.S. atomic energy program) launched a vigorous program to create a commercial supply of radiation measuring equipment. This effort was successful, and a variety of good equipment for almost all types of peacetime requirements is now available. Included are dose rate meters or survey meters that detect and measure radiation levels (the rate at which the radiation dose is being delivered) and dosimeters that measure total dose (the accumulated amount of radiation to which a person is exposed). The analogue of an automobile's speedometer and odometer helps. The speedometer measures the rate (miles per hour) the car is travelling; the odometer measures the distance (number of miles) the car travels. Survey meters provide information required to locate contaminated areas and to estimate the degree of the radiation hazard. Dosimeters record the total amount of an individual's radiation exposure.

These peacetime instruments would be of limited value in the event of a major radiological disaster such as an all-out nuclear attack or even the detonation of a single nuclear weapon. The sensitivity ranges of the instruments are much too low and the quantities of instruments available are much too small. Peacetime devices generally are limited to doses and dose rates in the milliroentgen and milliroentgen-per-hour range. (The roentgen, which is about the same as a rem or a rad, is the measurement unit used in civil defense instruments.) Radioactive fallout from one or more nuclear detonations could create, in unprotected areas, radiation levels of hundreds to thousands of roentgens per hour (R/hr.) and doses of hundreds to thousands of roentgens (R).

A source of radiological instruments that has been suggested for use in protecting the public in the event of a nuclear attack is our military services. The problem, of course, is availability. The military would need the instruments for their own operations. But even if all the military equipment some how could be released for civilian use, the total quantity would still fall far short of the civilian need.

Another possibility for meeting civilian needs in the event of a major nuclear disaster would be to improvise. Let everyone make his or her own instruments. Indeed, several versions of a homemade device have been proposed, but none has proved satisfactory. Even if an individual were to make a device that responded to radiation, there would be no way to check its calibration. Therefore, it would be impossible to know how high the radiation levels were and, hence, the degree of danger they would represent. The chances of a successful design for a do-it-yourself device seem very dim indeed. Experience has shown that quality components are required and that the requisite expertise and skills for acceptable design and fabrication require years of experience. More companies that have endeavored to produce radiation detecting and measuring equipment have gone out of business than have survived.

The lesson is that reliance on improvisation or short lead-time commercial production is unwise. If a nuclear attack should occur, survivors would have to rely on those supplies that had been purchased, distributed, and maintained specifically for civil defense purposes. To expect to augment these supplies during some short-term crisis period is highly unrealistic.

One more option for meeting the needs of radiological equipment is to adopt the policy that citizens--or at least every family--should buy their own radiation monitoring devices. Perhaps in the future, such a policy will make sense **if** simple, multipurpose, inexpensive instruments were developed and **if** people were motivated to buy them. But that is not the case today and, according to experts, will not be for many years to come, if ever.

The Federal Government has procured a sizeable stockpile of radiological equipment, most of which is still workable. Most of these instruments have been granted to State and local governments for use by their emergency personnel, but the total quantities involved fall far short of national civilian needs. Also, this equipment represents the state of technology at the time it was manufactured--the early 1960's. Since that time, the electronics industry has made great strides. Now, solid state devices have replaced entire circuits, and vacuum tubes have almost become a thing of the past. Although the old instruments perform well, costs of their maintenance and calibration continue to mount.

As in any field in which technology is changing rapidly (for example, military and commercial aircraft; pocket calculators; and cameras), at some point it becomes cheaper and more effective to take a quantum leap and go for a new design. Not only the savings in costs but also the improvement in performance outweigh the advantages of continuing with older equipment.

In the case of radiological instruments, the time to move on to new equipment has arrived. New, proven, less expensive, and more reliable dosimeters have been designed, are now in the final stages of production engineering and will be completed by the time manufacturing could get underway. The design of replacement dose rate meters is not far behind, and within a year or two, they will also be ready for production. The old equipment can be kept operable to fill in if needed until it can be replaced with the new.

Chapter 2

NATURE AND SCOPE OF THE RADIOLOGICAL THREAT

Radiological hazards associated with nuclear attack far outweigh hazards associated with any peacetime radiation disaster. This chapter, therefore, concentrates on the wartime problem. Also, since of the three types of radiation emitted by radioactive fallout, gamma radiation is the most serious and difficult to protect against, the discussion is oriented toward the gamma hazard.

There are too many unknowns, indeed "unknowables," to allow accurate prediction of the full effects of a nuclear attack--or even of a nuclear terrorist incident--including how much and where fallout would be deposited. The "unknowables" include factors such as:

- Size of the attack.
- Whether it would be aimed at population, military installations, industry, or combinations of these.
- Weapon details.
- Weight and timing of the attack.
- Weather and climate during and after the attack.

But there are also many knowns--enough to support important statements about nuclear weapons effects and to provide a basis for discussion and planning. Although we cannot predict the potential radiological hazard for any specific location, we can identify areas at greater risk. For example, locations up to a few hundred miles to the east of concentrations of missile silos or strategic air bases would be at higher risk because high altitude winds that would transport fallout usually blow from west to east.

For a given set of assumed attack conditions, we can calculate fairly realistically the answers to questions such as:

- What would the average fallout radiation doses and dose rates be over the United States land area?
- How would these doses and dose rates vary from one place to another?
- How would the dose and dose rates change with time after the attack?

The following answers to these questions have been calculated for a very large, theoretical attack. Assumptions were made about attack details, weapon yields, and weather.

The average "H + 1" dose rate over the country would be about 500 R/hr., and the average four-day dose about 1,125 R. (The H + 1 dose rate for a location is the hypothetical or theoretical dose rate that would occur at that location at one hour post detonation if the fallout from that detonation at that location occurred within the first hour after the detonation. Knowing the H + 1 value is useful in calculating how the dose rates would reduce as time goes by.) At the end of a four-day period (H + 96), the H + 1 dose rate of 500 R/hr., would be reduced to about two R/hr. If the 500 R/hr. and 1,125 R values were reduced by a factor of 40, which could be achieved readily in the sub-basement of a large building or in a specially constructed fallout shelter, the corresponding one-hour dose rate would be about 12.5 R/hr. and the four-day dose about 30 R. Computer-based calculations of how an average one-hour dose rate of 500 R/hr. and an average four-day dose of 1,125 R might vary over the country are given in Figure 1.

Figure 1

CALCULATED DISTRIBUTION OF DOSE RATES AND DOSES OVER THE U.S.

Percent U.S. Land Area	H + 1 Dose Rate (Roentgens/Hr.)		Four-Day Dose (Roentgens)	
	From	To	From	To
10	0	110	0	170
20	110	220	170	330
35	220	520	330	830
20	520	990	830	1700
14	990	1650	1700	3300
1	1650	3300	3300	10000

NOTES

1. Dose rates in the second and third columns are the so-called standard dose rates that would occur one hour after detonation if all fallout were deposited by that time.

2. The last two columns refer to the dose expected during the first four days following the assumed attack. This four-day dose is often used as an index to the amount of acute biological damage to be expected from radioactive fallout.

3. In the calculations that produced the numbers above, it was assumed that all weapons were detonated at the same time.

How these dose rates would change with time can also be estimated (see Figure 2). Through a process called radioactive decay, dose rates reduce rapidly at first and then more slowly as time passes. For about the first six months, the so-called "seven-ten rule" applies. After all the fallout is on the ground, for every seven-fold increase in time since the weapons were detonated, radiation levels reduce by a factor of ten. After about six months, the reduction in dose rates with time is faster than the seven-ten rule would predict. The seven-ten rule applies only if the fallout remains undisturbed—that is, no decontamination operations are performed and the weathering effects are negligible.

Figure 2

PERCENTAGE OF U.S. LAND AREAS SUBJECTED TO VARIOUS DOSE-RATE RANGES AT VARIOUS TIMES AFTER THE ASSUMED ATTACK

Time (Post Attack)		10%	20%	35%	20%	14%	1%
	(Roentgens/Hr.)						
1 hour (H + 1)	0	110	220	520	990	1650	3300
2 days	0	1.1	2.2	5.2	9.9	16.5	33
3 days	0	.69	1.4	3.2	6.1	10	21
	(Milliroentgens/Hr.)						
100 hours	0	440	880	2080	3960	6600	13200
6 months	0	4.4	8.8	21	40	66	132
2 years	0	.11	.22	.52	.99	1.7	3.3
5 years	0	.022	.044	.104	.20	.33	.66
25 years	0	.0011	.0022	.0052	.01	.017	.033

NOTES

1. At 100 hours, there is a switch from roentgens to milliroentgens.

2. All of the above values are based on the assumption that the fallout remains wherever it is deposited which, of course, is a poor assumption particularly at the later times. The important point is that the amount of radioactivity necessary to produce the above exposure rates would still be in existence at the times indicated. Radioactivity cannot be destroyed. Some might migrate or physically be moved, but the remainder would have to be dealt with. Wind, rain, traffic, decontamination, and other factors would cause the fallout material to move around. It is helpful to think of radioactive fallout as being much like a fine beach sand and thus subject to the same kinds of movements.

Chapter 3

CONSEQUENCES OF RADIATION EXPOSURES

The unit of radiation measurement, the roentgen, is not a familiar unit such as the mile, the pound, or the hour. Few patients would ask their dentists how many "milliroentgens" would be involved in a dental X-ray, and few would inquire of their radiologists about the roentgen dose in an upper GI series. This chapter gives meaning to the roentgen unit to provide perspective on the radiation threat described in the previous chapter.

Figure 5 is based on material taken from the National Council on Radiation Protection and Measurement's Report #42, "Radiological Factors Affecting Decision-Making in a Nuclear Attack" (1974).

Figure 3

PROBABLE EFFECTS OF BRIEF WHOLE-BODY EXPOSURE TO GAMMA RADIATION

Exposure Range (Roentgens)	Probable Condition of Majority During Emergency		Probable Death Rate During Emergency	Comments
	Medical Care Required	Able to Work		
0-50R	No	Yes	None	No symptoms
50-200R	No	Yes	Less than 5 percent	Deaths will occur in 60 or more days
200-450R	Yes	No*	Less than 50 percent	Deaths will occur within 30-60 days
450-600R	Yes	No*	More than 50 percent	Deaths will occur in about one month
More than 600R	Yes	No	100 percent	Deaths will occur in two weeks or less

*Except during illness-free latent period.

The human body has ways of repairing damage done to it. A radiation dose that would cause death if received in a few days or less might cause no detectable effects if spread out over a year or so. Figure 4 shows the expected effects of radiation exposures received over differing periods of time (also taken from The National Council on Radiation Protection and Measurement's Report #42.)

Figure 4

RECOMMENDED SYSTEM FOR PREDICTING OUTCOME OF GAMMA RADIATION EXPOSURE (THE "PENALTY" TABLE)

Medical care needed by	**Accumulated radiation exposures (R) any period of . . .**		
	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	---

At exposure levels where there would be none of the so-called acute effects (nausea, vomiting, loss of hair, and other signs of radiation sickness), other forms of biological damage could occur. Included would be higher-than-normal chances of developing cancer or leukemia and of producing offspring suffering from genetic damage. For gamma radiation exposures, it is estimated that each roentgen of gamma radiation exposure increases the risk of developing some malignancy (cancer or leukemia) by about one or two chances in 10 thousand.

In assessing genetic damage to the population, full account should be taken of the harm to be expressed in all future generations. An estimate of this risk would be about 30 to 40 such effects per million person roentgen or, expressed differently, a risk of 30 to 40 per million persons per roentgen exposure. This is about one-third the value cited above for the risk of fatal induced cancer.

Perspective can also be gained through examination of peacetime levels of exposure and safety limits applied in today's society. The average dose in the United States from external terrestrial radionuclides is about 40 milliroentgens per year. This is about 0.0046 mR/hr. The average dose throughout the country from cosmic radiation is about 28 milliroentgens per year (0.0032 mR/hr.). Doses, of course, vary from place to place. The highest whole-body total of 125 milliroentgens per year (0.014 mR/hr.) from all sources occurs in the city of Denver, where both cosmic and terrestrial components are higher than average.

It is noted that recently (since late 1984), radiological health protection personnel have become aware of a hazard due to radioactive gas (radon) accumulating in confined spaces such as some well insulated homes. The degree and distribution across the country of this hazard is yet to be fully evaluated.

The allowable maximum exposure for the general public (for other than medical purposes) recommended by the National Council on Radiation Protection and Measurement is 0.5 roentgens per year. If received at a constant rate over the year, this would be 0.057 mR/hr The allowable maximum exposure for radiation workers (those working in nuclear power plants or uranium mines or in the fields of nuclear medicine or radiology) is 10 times that value—five R/year—which, at a constant rate of 24-hours-a-day exposure, would be 0.57 mR/hr.

For the assumptions used, we have reasonable confidence in the above calculations about the percentages of U.S. land that would be subjected to various amounts of fallout. However, we have much less confidence in predicting which parts of the country might be so affected. At least theoretically, any section of the country would be at risk in the event of a nuclear attack and could be affected by serious levels of fallout. Since there would not be adequate time following an attack before the fallout would become extremely dangerous, radiological instruments must be in place if they are to be available when needed. In short, radiological instruments are needed wherever there are people.

Chapter 4

HISTORY AND CURRENT STATUS OF THE RADIOLOGICAL DEFENSE (RADEF) INSTRUMENT PROGRAM

Even before President Truman signed the legislative act that created our modern civil defense program (January 12, 1951), the national need for special radiological instruments for civil defense had been recognized. In December 1950, letters signed by James J. Wadsworth, an official in the Executive Office of the President, had been sent to State Governors encouraging them to obtain such instruments. The Federal Civil Defense Administration (FCDA) offered to pool the State orders to obtain more favorable prices through procurement in quantity. The National Bureau of Standards (NBS) had agreed to make tests to ensure the quality and correct calibration of the instruments purchased. All procurement costs were to be the responsibility of the States. Testing and calibration costs would be borne by the NBS.

North Korea had invaded South Korea the previous June, and U.S. combat forces were actively engaged in battle on the Korean peninsula. Further, our relations with the Soviet Union, which was known to possess nuclear weapons, were strained. Nevertheless, the States were not responsive, and no procurement was undertaken.

As a next step, the FCDA worked out an arrangement with the Atomic Energy Commission (AEC) whereby AEC instruments and small radioactive sources were loaned to the States for training. While many of the States took advantage of this program, they recognized its deficiencies. After the initial training, the instruments had to be returned, leaving no capability for refresher training or for radiological monitoring in the event of an emergency. This was somewhat like training soldiers with wooden guns but never providing the real ones. Subsequently, to augment the AEC supplies, FCDA purchased some low-range Geiger counters (later known as the CDV-700s).

Certain States, notably New York and California, initiated limited procurement actions to obtain operational instruments. But by and large, the need for such equipment went unmet. Finally, it was recognized that the policy of depending on the States to provide their own radiological monitoring equipment simply would not work. The FCDA and Congress accepted that the Federal Government must assume responsibility for the radiological instrument program including design, engineering, procurement, and maintenance and calibration.

In December 1960, the Office of Civil and Defense Mobilization (OCDM) issued an advisory bulletin announcing to the States the availability, on a grant basis, of radiological monitoring instruments for operational purposes. OCDM recommended establishment of a nationwide network of 100,000 (later increased to 150,000) monitoring stations to provide radiological information for survival and recovery actions at the State and local levels. Each monitoring station that met the specified requirements was to be granted a set of instruments consisting of:

- A CDV-700 Low-Range Radiological Survey Meter, Geiger Counter, probe type, beta-gamma discriminating, 0-0.5, 0-5, and 0-50 mR/hr.

- A CDV-710 High-Range Radiological Survey Meter, gamma only, 0-0.5, 0-5, and 0-50 R/hr. (In later procurements, the CDV-710 survey meter was replaced by a CDV-715 Radiological Survey Meter, gamma only, with an additional range of 0-500 R/hr.)

- A CDV-715 High-Range Radiological Survey Meter, gamma only, 0-0.5, 0-5, and 0-500 R/hr.

- A CDV-720 High-Range Radiological Survey Meter, beta-gamma discriminating, with a range of 0-5, 0-50, and 0-500 R/hr.

- A CDV-730 Radiological Dosimeter, Self-Reading gamma only, 0-20 R.

- A CDV-740 Radiological Dosimeter, Self-Reading, gamma only, 0-100 R. (In later procurements, the CDV-730 and -740 dosimeters were replaced by a CDV-742 Dosimeter, self-reading, gamma only, 0-200 R.)

- A CDV-750 Radiological Dosimeter Charger.

In the early 1960's, the Department of Defense's Office of Civil Defense (OCD) embarked on a program to locate and stock naturally occurring fallout protective space in existing buildings. Included in these stocks were radiological instruments. In May 1964, OCD announced the availability of shelter instruments. For shelters meeting the specified criteria, assembled "Shelter Radiation Kits" were provided. Each kit contained one CDV-700, one CDV-715, two CDV-742s, and one CDV-750.

Other special requirements were identified, and appropriate instruments were designed and procured. These instruments included the CDV-700M for radioiodine measurements, the CDV-717 for remote readings, the CDV-138 for training, the CDV-781 for aerial surveys, and the CDV-711 for external readings from a hardened site such as an emergency operating center (EOC). A chronological account of radiological instrument procurement is shown in Figure 5. It does not include procurement of radioactive source sets used in training.

Figure 5

RADIOLOGICAL DEFENSE INSTRUMENT PROCUREMENT
(includes spare parts)

Fiscal Year	Funds Obligated	Items Procured
1955	$ 1,555,000	146,768
1956	4,441,000	387,166
1957	3,944,000	347,280
1958	0	0
1959	1,822,000	114,395
1960	2,855,000	167,800
1961	4,191,000	256,177
1962	23,295,000	2,712,964
1963	8,750,000	1,191,450
1964	1,901,000	400,000
1965-85	0	0
TOTAL	$53,151,000	5,724,000

Procurement through FY 64 provided sufficient instruments for:

- One set of monitoring instruments for each of 150,000 stations.
- A second set of monitoring instruments for each of 50,000 stations.
- One kit of monitoring instruments for 200,000 shelters.
- 2.4 million dosimeters for emergency workers.
- 1,500 training sets (150,000 instruments).
- 14,510 high school monitoring kits (160,000 instruments).
- 1,250 aerial survey meters.
- 200 remote blast-resistant survey meters for EOCs.

Over the years, some of these instruments have been lost or destroyed or have simply become inoperative. However, a substantial number remain in the current inventory, as shown in Figure 6.

Figure 6

EXISTING INVENTORY OF RADIOLOGICAL DEFENSE INSTRUMENTS

Instrument (CDV-)	Inventory
742	2,561,600
715	483,900
750	412,200
700	353,800
730	114,000
740	113,500
138	102,400
717	90,900
720	61,200
784	1,707
782	1,440
781	1,250
711	400
700M	300
757	80
794	74
790	51

In summary, the inventory currently consists of over four million instruments. This inventory, most of which is in good working condition although clearly inadequate for total national needs, represents a significant national resource for civilian protection in the event of a nuclear emergency.

Chapter 5

THE RADEF INSTRUMENT MAINTENANCE AND CALIBRATION PROGRAM

Radiological defense instruments must be routinely inspected (operationally checked), periodically calibrated, and repaired as needed to ensure reliable performance at any moment of need. When the States requested radiological equipment from the Federal Government, under the terms and conditions of the requisition form, they agreed "to maintain it in a proper operating condition."

Early on, it became evident that the States, relying on their own resources, could not meet the terms of this agreement. Even after the Federal Government began to provide 50 percent matching funds to the States for this purpose, it was recognized that there was little, if any, possibility of achieving a nationwide program that would ensure proper instrument maintenance and calibration. At this point, the U.S. Army was directed by the Secretary of Defense to conduct a comparative cost study for feasible alternative methods of inspecting, maintaining, and calibrating civil defense radiological instruments. As a result of this study and based on a pilot experiment in Nebraska, a decision was made to implement a 100 percent Federally-funded program in all States. Funding for this program for fiscal years 1962 through 1985 totaled over $68 million.

At the beginning of FY 85, 151 full-time State personnel were being 100 percent Federally-funded under Comprehensive Cooperative Agreements (CCAs) with States for the annual inspection, maintenance, and calibration of one-quarter of the 4,300,000 instruments distributed nationally. The instruments are processed in specially equipped State shop facilities. In addition to maintenance and calibration, the States' highly trained technicians have performed special retrofits designed to upgrade performance and modernize equipment. Retrofitting has reduced the maintenance cycle for instruments to once every four years in contrast to the two-year cycle previously required.

Funds allocated to radiological defense instrument maintenance and calibration through the years have exceeded the original cost of instruments in the inventory. However, the cost of the program has more than paid for itself by maintaining this tremendous national resource--one that has steadily increased in value. Because of this program, these instruments actually perform better and are more reliable today than when they were bought.

Chapter 6

RESEARCH AND DEVELOPMENT OF RADEF INSTRUMENTS

Within months after President Truman established the Federal Civil Defense Administration (1951), an instrument field test program was initiated in conjunction with a nuclear weapon test operation at Bikini Atoll. This series called Operation Greenhouse was the first of many tests of radiological instruments in the field under actual fallout conditions. These experiences were invaluable in establishing not only the technical requirements of the equipment but also in setting human engineering criteria.

Since cessation of atmospheric weapons tests in the early 1960's, instrument engineers have had to rely on laboratory simulations for performance testing. The FEMA Radiological Instrumentation Test Facility (RITF) established in 1965, serves this purpose. This test facility provides advice and guidance to the State maintenance and calibration shop facilities. It also performs procurement acceptance testing, dosimeter development, and repair. In addition, the RITF develops procurement specifications for all FEMA radiological instruments.

Other substantial contributors to the development of civil defense radiological instruments include the following:

- The Department of Energy (DOE)--formerly the Atomic Energy Commission--provided opportunities to field test equipment in connection with nuclear weapons test programs. DOE laboratories, especially Brookhaven National Laboratory, Oak Ridge National Laboratory, and Idaho National Engineering Laboratory, have been active participants over the years in the radiological instrument program. Sometimes this has involved a transfer of funds, but frequently there was no cost to the civil defense agency.

- The National Bureau of Standards (NBS) has been involved in the instrument program since the early 1950's, testing instrument designs and helping to prepare procurement specifications. NBS continues to participate by providing radiation standards to support nationwide radiological instrument calibration activities. Currently, NBS is working on the development of a novel approach to a low-cost dosimeter using radiochromic dyes.

- The Army and the Navy are active participants in the FEMA instrument development program. The Navy Electronic Systems Command has provided much of the financial support for the development of the new low-cost dosimeter. This device will be capable of meeting the Navy's rigid specifications. The U.S. Army Electronic Research and Development Command Laboratory at Fort Monmouth, New Jersey, provided the bulk of the funds for development of new radiation-resistant insulating material for the new dosimeter. The Army is also participating in research on the feasibility of a low-cost radiochromic dye dosimeter.

- Individual States have made major contributions. For example: California provided early statistics on changes in performance of survey meters so that an orderly retrofit program could be implemented; Wisconsin field tested the aerial survey meter; many State maintenance and calibration shop facility personnel have made valuable suggestions about instrument maintenance and repair.

A recent addition to technical facilities contributing to the radiological instrument program is the William Langer Jewel Bearing Plant, Rolla, North Dakota. Here, pilot production of low-cost radiological instruments is undertaken to: proof test instrument designs, assist in the solution of engineering problems, assist in the incorporation of the results of pilot production experience into procurement specifications, and share the technology with the private sector. With this pilot production experience base, availability of detailed construction and performance specifications, and support of other technical organizations as needed, a competent private-sector production plant should be able to produce low-cost equipment that meets the stringent requirements of radiological instruments for emergency purposes.

Chapter 7

RADEF INSTRUMENTS: EXISTING AND UNDER DEVELOPMENT

EXISTING INSTRUMENTS

The current instrument inventory was designed for response to the nuclear attack threat of the 1960's, when much radiological planning was based on readily available communication capability. A network of weapons effects reporting stations (WERSs) strategically located throughout jurisdictions was to provide local EOCs with data on weapons effects damage and fallout radiation. However, it is now understood that the effects of electromagnetic pulse (EMP) could severely reduce the effectiveness of the WERSs. In addition, EMP could greatly reduce the ability of shelters, congregate care centers, and key worker shelters to communicate with EOCs and Emergency Broadcast Stations. As a result, the local radiological protection system must be based on decentralized management principles. This decentralization requires that instruments and trained personnel be available to support in-place shelters, upgradeable shelters, expedient shelters, and key worker shelters.

Peacetime radiological threats require availability of low-range ratemeters and dosimeters. All low-range ratemeters and dosimeters currently in the inventory were acquired to support training. As a result, the instruments have experienced a fair amount of use. Furthermore, the instruments were not intended to support peacetime radiological emergencies, only radiological training.

It is important to understand the use of radiological instruments and grasp how personnel would use various radiological instruments to perform critical functions. This report analyzes requirements for three types of radiological instruments: wide-range ratemeters, dosimeters, and chargers.

Wide-range Ratemeters

A wide-range ratemeter is a portable instrument, such as a Geiger counter or ionization chamber, used to detect ionizing nuclear radiation and to measure the amount of ionizing (or nuclear) radiation to which an individual would be exposed per unit of time, expressed as roentgens or milliroentgens per hour. It provides radiation information required for locating contaminated areas and for estimating the degree of the hazard in roentgens or milliroentgens per hour.

The ratemeter would be used by citizens to find the safest locations in fallout shelters and to improve the protection afforded by shelters through expedient use of shielding materials. In the post shelter period, they would be used to monitor radiation exposure in recovery operations. Ratemeters are required for all types of radiological emergencies. The ratemeter must cover a wide range of radiation levels and present the radiation data in a way that allows the user to make the right decision.

Dosimeter

Dosimeters are used for measuring and registering total accumulated exposure to ionizing radiation. Dosimeters would provide shelterees and emergency workers information on the total amount of exposure to radiation. In any disaster involving intense and uncontrolled exposure of many people to nuclear radiation, the objective is to minimize the number of lives lost; the number of people with incapacitating sickness; the long-term biological effects; and impediments to industrial, agricultural, and social recovery of the area.

Because problems of radiation exposure are accompanied by other aspects of any disaster and also by other requirements of the populace and the government, many complex decisions must be made. When a decision is required regarding additional exposure to radiation, four questions must be answered before the decision can be made.

(1) How large is the accumulated exposure up to that time, and over what period(s) of time was it received?

(2) Is the physical condition of the individual(s) consistent with the predicted effect of such an exposure received in that period time?

(3) How large is the proposed additional exposure and the duration of this exposure?

(4) What is the physical condition of the individual(s) likely to be after the additional exposure?

It would be the responsibility of the decisionmaker to weigh the probable outcome for individuals against the probable outcome for a (usually) larger group of people if the proposed action (e.g., obtaining water, food, medicines) were not carried out. The major question to be answered under nuclear attack conditions before accepting additional radiation exposure would be: How much radiation injury will be caused by particular total exposures accumulated in particular time intervals? The dosimeter provides baseline data on individual accumulated radiation exposures against which such decisions can be made.

Charger

A charger is a device to read and apply the proper electrostatic charge to rezero self-indicating electrostatic dosimeters.

Figure 7 provides an overview of the performance characteristics of the current inventory of radiological instruments.

Figure 7
(Part 1 of 5)

CHARACTERISTICS OF RADIOLOGICAL EQUIPMENT IN THE CURRENT INVENTORY

CDV-700	Highly sensitive, low-range radiation survey meter that can measure gamma radiation and discriminate between beta and gamma radiations.
Range:	0-0.5, 0-5.0, 0-50 milliroentgens (mR) per hour.
Detects/Measures:	Detects beta and gamma radiation; measures gamma radiation only.
Accuracy:	±15 percent of true exposure rate from cobalt-60 or cesium-137.
Calibration:	Performed by State Radiological Instrument/Maintenance & Calibration (RI/M&C) facilities.
Response Time:	95 percent of final reading in approximately eight seconds.
Temperature:	Instrument will operate properly from -10° to +125° F.
Pressure:	Instrument will operate properly from sea level to 25,000 feet.
Jamming:	Exposure rates from 50 mR per hour to one roentgen (R) per hour will produce off-scale readings.
Light Sensitivity:	Direct sunlight will not affect the operation of the instrument.
Electromagnetic Interference:	The instrument will operate properly in normally encountered electromagnetic fields.
Operational Check, 1 Source:	A permanently sealed radioactive source will provide a reading of 2 mR/hr ±0.5 mR/hr when the probe, with beta shield open, is held over it.
Battery Life:	100 hours continued use (minimum).

Figure 7
(Part 2 of 5)

CDV-715	A high-range gamma survey meter for general post attack operational use. The detecting element of the CDV-715 is an ionization chamber. The instrument is designed for ground survey and for use in fallout shelters.
Range:	0-0.5, 0-5.0, 0-50, 0-500 R per hour.
Detects/Measures:	Gamma radiation only.
Accuracy:	±20 percent of true exposure rate from cobalt-60 or cesium-137.
Calibration:	Performed by State RI/M&C facilities.
Spectral Dependency:	±15 percent for gamma radiation energies between 80 Kilo-electron Volts (KeV) and 1.2 Mega-electron Volts (MeV).
Response Time:	95 percent of final reading in nine seconds.
Temperature:	Instrument will operate properly from -20° F to +125° F.
Pressure:	Instrument will operate properly from sea level to 25,000 feet.
Jamming:	Exposure rates from 500 R per hour to 5,000 R per hour will produce off-scale readings at the high end.
Electromagnetic Interference:	Instrument will operate properly in normally encountered electromagnetic fields.
CDV-717	Modification of the CDV-715. The CDV-717 is equipped by the manufacturer with a removable ionization chamber attached to 25 feet of cable. This provides a remote reading capability for fallout monitoring stations. Operating characteristics and specifications are the same as for the CDV-715.
CDV-720	A high-range (0-500 R/hr) beta-gamma survey meter designed for post attack use by monitors. The detecting element is an ionization chamber. The chamber has an aluminum window on the bottom to permit detection of beta particles. The bottom of the instrument case contains a sliding shield to permit discrimination against beta particles, if desired. Only gamma radiation can be measured.

Figure 7
(Part 3 of 5)

CD DOSIMETERS	There are three self-indicating (direct reading) electrostatic dosimeters for operational use: CDV-730 (0-20 R), CDV-740 (0-100 R), and the CDV-742 (0-200 R). For training purposes, the CDV-138 (0-200 mr) dosimeter is recommended.

		On-Hand Quantity
Range:	CDV-138 (0-200 mr)	102,400
	CDV-730 (0-20 R)	114,000
	CDV-740 (0-100 R)	113,500
	CDV-742 (0-200 R)	2,561,600

Detects/Measures:	Gamma radiation only.
Accuracy:	±10 percent of true exposures from cobalt-60 or cesium-137.
Calibration:	Performed by State RI/M&C facilities.
Spectral Dependency:	±20 percent of true exposure for gamma radiation energies from 50 Kev to 2 Mev.
Electrical Leakage:	CDV-730 and CDV-742. Beginning 10 minutes after exposure, leakage will not exceed five percent of full scale in a four-hour period. Beginning 48 hours after exposure, leakage will not exceed two percent of full scale in 96 hours. CDV-740. Leakage will not exceed two percent of full scale in 24 hours. CDV-138. Beginning 10 minutes after exposure, leakage will not exceed five percent of full scale in four hours. Beginning 48 hours after exposure, leakage will not exceed three percent of full scale in 48 hours.
Geotropism:	Reading will not vary more than ±4 percent of full scale when rotated about the horizontal axis.
Temperature:	Instrument will operate properly from -40°F to +150°F.
Pressure:	Instrument will operate properly from sea level to 25,000 feet.
Shock:	Instrument will operate properly after four drops from a height of four feet onto a hardwood floor.

Figure 7
(Part 4 of 5)

CDV-750	Dosimeter charger is used to read and charge self-indicating electrostatistic dosimeters.
Temperature:	Instrument will operate properly from -20° F to +125° F.
Pressure:	Instrument will operate properly from sea level to 25,000 feet.
Shock:	Instrument will operate properly after six four-foot drops onto a hardwood floor.

CDV-757	A barrier shielding demonstration set. A low-range radiation detection instrument coupled to a neon-lighted remote readout indicator that is readily visible in large conference rooms or small auditoriums. Contains a one millicurie cesium-137 source. A license is required for possession and use.

CDV-781	Aerial survey meter designed for use in relatively low-flying air-craft. Use of aerial survey permits coverage of large areas quickly and allows highly contaminated areas to be monitored with minimum exposures to operating personnel.
Range:	0-0.1, 0-1.0, and 0-10 R/hr. (corresponding to much higher ground levels depending on the flight altitude).
Detects/Measures:	Gamma radiation only.
Accuracy:	±10 percent of true exposure rate from cobalt-60 or cesium-137.
Calibration:	Performed by State RI/M&C facilities.
Temperature:	Instrument will operate from -20° F to 110° F.
Humidity:	To 95 percent.
Altitude:	Designed to withstand flights of up to 20,000 feet and will function at altitudes of less than 1,000 feet.
Operating Time:	40 hours on nine flashlight (D cell) batteries.
Tracking Error:	Between the simulator dials and the metering dials will not be more than 10 percent.

Figure 7
(Part 5 of 5)

Reading Time:	Not less than 15 seconds—preferably one minute.
Shock and Vibration:	Instrument is designed to withstand normal shock and vibration encountered in small aircraft operation.
Detector Unit:	Contains three special Geiger-Mueller tubes.
Warmup Time:	Two minutes.
CDV-790	A low-range survey meter calibration unit designed to provide a gamma radiation field for calibrating CDV-700 instruments. It contains approximately 16 millicuries of cesium-137 as the calibration source. Radiation levels of 1.6 to 40 mr/hr. are produced. A license is required for possession and use.
CDV-794	A high-range survey meter calibration unit containing a cesium-137 source of approximately 130 curies. The unit is designed to provide suitable protection from radiation hazards to the operator while providing a high intensity gamma radiation field for calibrating CDV-715 instruments. Radiation levels of 0.4, 4, 40, and 400 R/hr. are produced in the exposure chamber. A license is required for possession and use.

From FEMA CPG 2-6.2, Radiological Defense Manual, June 1977.

INSTRUMENTS UNDER DEVELOPMENT

Procurement of instruments to meet deficiencies must take into consideration:

- Procurement cost.
- Accuracy.
- Range.
- Response time.
- Ruggedness.
- Maintenance cost.
- Ease of operation.
- Long-term storage (20 years or more) without deterioration.

Major technological advances have occurred in dosimeters and chargers since the original instrument procurement. These advances include:

- Development by FEMA of a reliable plastic direct-reading carbon fiber dosimeter that has the potential for low cost in mass production. This device is now in the pilot production phase at the Rolla facility. Pilot production will support reliable procurement data packages for mass production in the private sector.

- A piezoelectric charger for dosimeters developed by Oak Ridge National Laboratory (ORNL). No batteries are required, and simple circuitry promises low cost in mass production.

Other technological advances that promise major improvement in dose rate measurement are occurring.

- The U.S. Army and ORNL are developing wristwatch-size devices that can measure dose rate as well as accumulated exposure. The most promising approach uses a silicon photodiode as a detector. The key to a low-cost device of this type is availability of a standard microchip for the electronic circuitry.

- ORNL is working on two additional candidate ratemeter concepts. One uses the proven proportional counter as the detector. The other is based on use of inexpensive smoke detector components.

The new designs of both dosimeters and ratemeters will meet and exceed the specifications identified for individual instruments in the current inventory. In addition, they promise to be cheaper, require less maintenance, be easier to operate, and meet long-term storage requirements (20 years or more) without deterioration.

The state of the art in fabrication of the new dosimeters and chargers has advanced to the point where, following a successful pilot production of the FEMA dosimeter (currently underway), procurement can be initiated from the private sector. Contract awards will be made on a competitive basis. FEMA-proven manufacturing processes will be required to ensure quality products. A new supply of low-cost, reliable instruments to meet emergency management operations requirements will then become available.

In the case of dose rate meters, additional research and development is required. The time period to complete the manufacturing specifications for procurement from the private sector is estimated at three years or more.

Chapter 8

THE RADIOLOGICAL DEFENSE (RADEF) SYSTEM

FEMA assists State and local governments in developing radiological defense (RADEF) programs where the first responsibility for radiological operations lies—at the State and local level. FEMA is responsible for developing, in coordination with other elements of the Federal Government and State and local governments, a radiological defense system to monitor and analyze the radiological hazards of a nuclear attack.

THE SYSTEM AT THE STATE AND LOCAL LEVELS

Since radiological instruments are a critical requirement for radiological protection actions that occur at the State and local levels, the following discussion focuses on the State and local radiological protection system. Concentration is on the State and local Radiological Defense Officer (RDO), the local Radiological Response Team (RRT), and the Radiological Monitor (RM), emphasizing their responsibilities for nuclear attack and peacetime radiological preparedness.

State

The State Emergency Management Agency and State Bureau of Radiological Health (or their equivalents) compose a State organization responsible for the State response to radiological emergencies. The organization includes Radiological Defense Officers at the State emergency operating center (EOC) for nuclear attack and limited peacetime radiological response as well as health physics personnel normally within the Bureau of Radiological Health for the full range of peacetime radiological responses. The Radiological Defense Officer's responsibilities are to:

- Serve as the point of contact at the State level for nuclear attack preparedness and for peacetime radiological emergencies.
- Organize the State and local RADEF system for nuclear attack radiological preparedness.
- Develop overall plans for the system.
- Manage the system on a daily basis.
- Ensure that monitoring personnel within the various emergency services are adequately trained for the first response function at the local level.
- Coordinate radiological emergency response from the EOC.
- Provide notification to the proper State agencies of radiological emergencies according to State plans.

- Interface with and support other State agencies having statutory responsibility for peacetime radiological emergency response.

In addition, the State has direct responsibility for aerial radiological monitoring in the event of nuclear weapon detonations.

State support organizations include State departments such as Agriculture, Transportation, and Health, and the National Guard, State Police, and State Fire Marshall. Each State is organized differently but generally has a department that interacts with its Federal counterpart and has a similar role.

Local

Local Radiological Defense Officer responsibilities are similar to those of the State Radiological Defense Officer. Local Radiological Defense Officers also coordinate and provide support to the local Radiological Response Team (RRT). The system should include three Radiological Defense Officers per operating area to allow multiple shift operation.

The local RRT is responsible for support to the initial responder and incident commander. Team members are recruited from the spectrum of public- and private-sector emergency service organizations—i.e., fire service, law enforcement agencies, hospitals, emergency medical services, utilities, public works, and health services. These personnel would serve as a cadre of highly qualified response personnel for each area. Generally, their responsibilities would include:

- Serving as a community-based cadre of radiological personnel for controlling radiological hazards due to transportation and other incidents, terrorist activities, accidental nuclear weapon detonations, or nuclear attack.

- Developing departmental plans and operating procedures for radiological response.

- Training their own organization's initial response personnel as Radiological Monitors for first-response actions to a radiological hazard.

- Conducting refresher/update training for Radiological Monitors.

- Serving as a cadre of instructors to conduct accelerated radiological training during a national emergency.

- Ensuring departmental availability, operability, and periodic maintenance and proper distribution of radiological instruments.

- Notifying the Radiological Defense Officer of radiological emergencies according to the local Radiological Protection Annex to the local Emergency Operations Plan (EOP).

Radiological monitoring personnel provide initial radiological protective measures at the scene of a radiological incident and support emergency response personnel and critical workers. RRT instructors train radiological monitors. Critical workers provide services essential to support the national defense and recovery from a major radiological incident.

PERSONNEL RESPONSIBILITIES IN A RADIOLOGICAL ENVIRONMENT

An outline of various personnel tasks depicts the types of operations that must be conducted in a radiological environment. These different tasks are listed below under the personnel categories to which they would be assigned: Radiological Monitors (RMs), RRTs, and Radiological Defense Officers (RDOs).

Radiological Monitor (RM) Responsibilities

- Perform operational checks on survey meters and perform basic maintenance operations (install batteries, zero, etc.).
- Use survey meters to determine the type and exposure rate of radiation.
- Use a dosimeter charger in zeroing a dosimeter.
- Use a dosimeter in determining accumulated dose of radiation.
- Apply the radiation protection principles of time, distance, and shielding in reducing exposure of the public to ionizing radiation from a nuclear weapon detonation.
- Use survey meters to identify areas of contamination.
- Support sheltered population by providing guidance on:
  - Actions to reduce radiation levels in shelters.
  - When restrictions on shelter living may be relaxed and how much.
  - When people may emerge from shelters.
  - Where and when emergency operations can be initiated and expected exposure levels.
  - When and where unprotected emergency recovery activities can begin.
  - Participate in refresher training and exercises.

Radiological Response Team (RRT) Responsibilities

RRT members have the responsibilities of Radiological Monitors plus the following:

- Apply the principles of radiation exposure control in selecting initial appropriate actions at the scene of an accident involving radioactive materials.
- Review radiation packaging labels and determine the potential threat of packaged materials.
- Establish a control area for accidents involving radioactivity.
- Initiate proper notification of an accident involving radioactivity.
- Provide initial advice and guidance on protective measures to safeguard the public and response personnel.
- In a nuclear attack situation, provide information on the radiation environment in the jurisdiction, particularly in shelters.
- Determine extent and severity of fallout radiation levels after a nuclear weapons detonation.
- Determine fallout arrival times after a nuclear attack.
- Train Radiological Monitors and participate in exercises, as required.
- Prepare organizational procedures.
- Execute response team plans in an actual or simulated radiological emergency.
- Ensure the availability, operability, periodic maintenance, and distribution of radiological instruments within the department or service.

Radiological Defense Officer (RDO) Responsibilities

RDOs have the responsibilities of RRTs and Radiological Monitors plus the following:

- Evaluate overall radiological annex to the EOP for deficiencies and overlap in functional responsibilities, identify problem areas, and develop solutions to planning problems.
- Provide a baseline of operational data for planning purposes to ensure plans are based on reasonable expectations.

- Recruit personnel to support the State and local radiological system.
- Ensure that all designated public shelters included in Emergency Operations Plans are provided with radiological instruments.
- Manage a radiological instrument maintenance program.
- Develop a system to ensure that radiological personnel are trained.
- Conduct radiological exercises to test operational response capabilities of the RADEF system.
- Ensure that all elements of the RADEF system are integrated and can function as a team.
- Evaluate available weapons effects data.
- Estimate future exposure rates.
- Advise the Radiological Response Team.
- Advise EOC personnel on radiological issues.
- Evaluate effectiveness of contamination control measures.
- Coordinate radiological protection support for recovery operations.
- Recruit and train aerial monitors.
- Analyze aerial radiological data and assess the implications in terms of operations.
- Ensure sufficient radiological instruments are on hand.

Four areas of radiological responsibility at the State and local levels have been covered in the outline above:

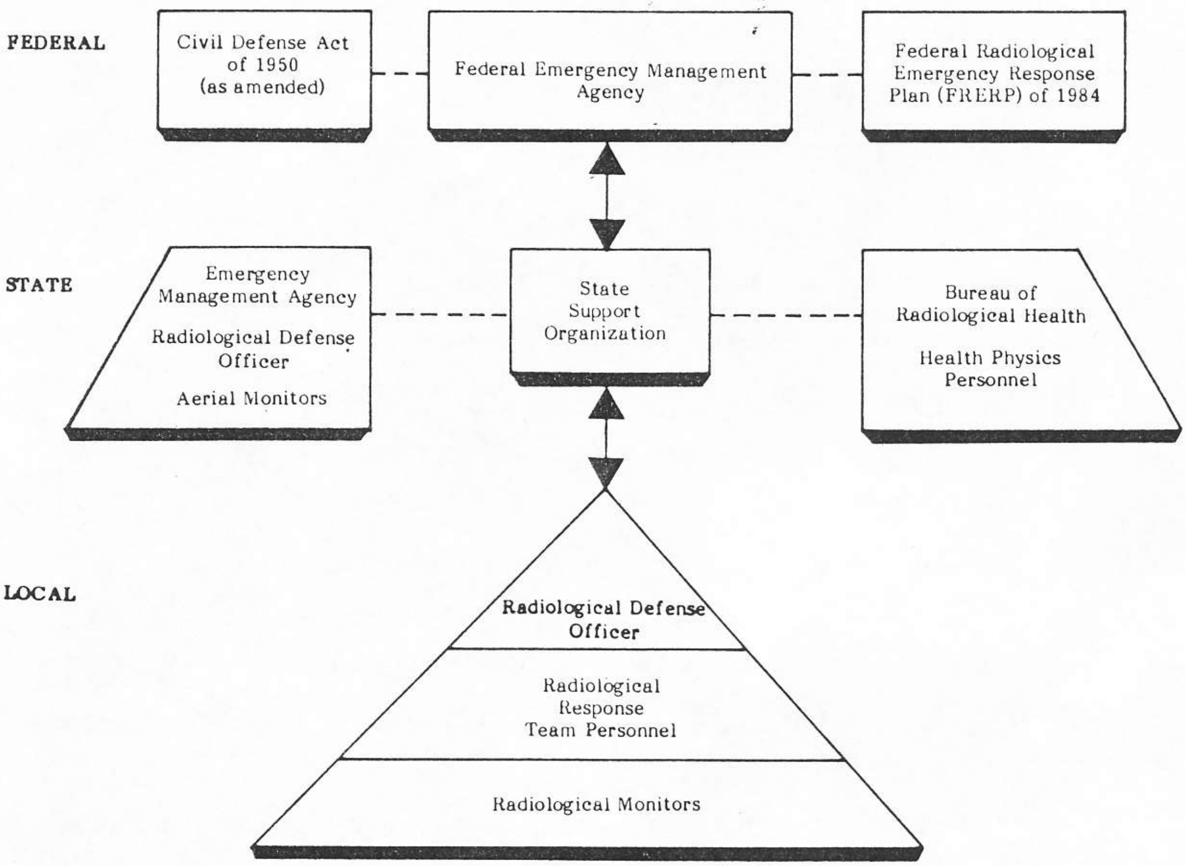
1. Radiological Defense Officers to develop and implement a radiological defense system within the jurisdiction for nuclear attack and other radiological hazards that threaten the jurisdiction.
2. A team of qualified radiological personnel (RRT) to support the first responders.
3. Radiological Monitors required to support survival and recovery during periods of international crisis.

4. Radiological Monitors with a first-response capability to detect radiation, to take appropriate action immediately, and to notify the RRT and other authorities.

The interactions of these areas of responsibility within the total radiological emergency response system are illustrated in Figure 8.

Figure 8

RADIOLOGICAL EMERGENCY RESPONSE SYSTEM



INSTRUMENTS FOR EMERGENCY WORKERS

All of the personnel categories described thus far are considered to be emergency workers. (An emergency worker is an individual who has a mission essential to protecting the health and safety of the public. Since emergency workers could be exposed to ionizing radiation, they must be trained.) This individual must be trained in the basic characteristics of ionizing radiation and its health effects. The individual must be able to determine his or her cumulative radiation dose with a direct-reading dosimeter and know what to do when dose limits and turn-back values are reached. Emergency workers may include the following: radiation monitoring personnel, traffic control personnel, personnel carrying out backup alerting procedures and essential services, and utility personnel. Essential services or utility personnel are considered emergency workers only when their services are required to protect the health and safety of the public.

To be useful, radiological instruments must be available directly to the people who may be exposed to radiation. This means that instruments must be in the hands of local personnel. For purposes of determining total instruments required, the numbers of people in the principal need categories are detailed in Figure 9. Information on critical workers and emergency services personnel in this figure has been determined from U.S. Department of Labor statistics.

Figure 9

NUMBERS OF INDIVIDUALS IN PRINCIPAL RADIOLOGICAL RESPONSE CATEGORIES

RADIOLOGICAL RESPONSE TEAMS		RADIOLOGICAL MONITORS			
		Emergency Services Personnel		Critical Workers	
3,450 operating areas x 30-person team (for 10-person, 3-shift operations) 3,450 x 30=	103,500	Police officers	566,701	Food Production	1,813,600
		Highways	548,177	Health and Medical	3,803,797
		Firefighters (paid)	202,779	Public Safety (first responders)	2,805,014
		Firefighters (volunteer)	736,000	Construction Maint. and Repair	4,457,605
		Sewage	82,468	Energy	2,042,901
		Water supply	113,949	Transportation	2,058,022
		Electric power	59,824	Communication and Electrical Support	1,153,749
		Gas supply	10,116	Information Support	2,106,966
		EMTs	485,000	Metal and Metal Processing	701,306
				Direct Defense Support	1,102,333
				Construction Support Industries	531,560
TOTALS	**103,500**		**2,805,014**		**22,587,013**

CONCEPT OF OPERATION

Having discussed the roles, functions, and relationships of various elements in the radiological response system, it is now possible to understand a broad overview of how these elements would function during a radiological emergency.

Counties, county equivalents, or other emergency management planning units comprise "operational areas." (In almost all the States, these areas are counties or county equivalents that have been used in existing data bases.) The number of operational areas identified in the U.S. today is 3,450 (50 States, two trust territories, and 3,398 local areas). This is consistent with the Integrated Emergency Management System (IEMS) process which recognizes that emergency management plans and systems are needed at all levels of government and in numerous private industries and organizations.

As described previously, each radiological operational area should have a 30-member RRT. Based on the personnel categories identified in Figure 9, a first-response capability consists of emergency services with the ability to measure radiation, to take immediate appropriate action, and to notify the RRT and other responsible State authorities. The RRT, a select team of highly qualified radiological personnel, is available to support the Radiological Monitors. During a period of international crisis, the total radiological protection system could be expanded through training of critical workers and public shelter radiological monitors by the RRT.

This Concept of Operation is designed to improve horizontal/vertical coordination, to consolidate resources, and to improve response. FEMA has developed nine radiological courses to support this Concept of Operation. The long-term plan is to expand the training of the RRT to include a total hazardous-materials capability.

Chapter 9

RADIOLOGICAL DEFENSE INSTRUMENTS IN THE INTEGRATED EMERGENCY MANAGEMENT SYSTEM

FEMA has developed the Hazard Identification, Capability Assessment, and Multi-Year Development Plan (HICA-MYDP) to establish a nationwide database for determining the status of emergency preparedness. As a planning tool, it can guide jurisdictions through a logical sequence of identifying hazards and assessing capabilities. The Integrated Emergency Management Systems (IEMS) recognizes eight generic functional areas in developing capabilities to deal with emergency preparedness and response. Radiological instrument support is a requirement to augment and reinforce these eight generic capabilities in order to develop a nuclear attack response and recovery capability. These eight generic functional areas are:

1. Direction, Control, and Warning

All equipment, facilities, and operations planning required to develop and maintain the capability to:

- Warn and inform all segments of the population.
- Direct and control emergency operations in an effective manner.
- Ensure continuity of government in time of emergency.

2. Population Protection

- Identification of requirements for evacuating and/or sheltering the population.
- Evacuation planning.
- Shelter survey.
- Shelter use planning.
- Shelter facility preparation.
- Shelter deficit planning.

3. Contamination Monitoring and Control

The instrumentation and operations planning required to develop and maintain the capability to:

- Identify and monitor all potential types of contamination.
- Control exposure.

- Provide technical guidance to decision-makers concerning prudent actions and countermeasures.

4. **Public Education and Emergency Information**

- The development and implementation of public awareness and preparedness programs for identified hazards.
- Plans and procedures for establishing a joint information center.
- Pre-event preparation of material for immediate release to public in time of emergency.

5. **Emergency Support Services**

- The development and maintenance of response capabilities within the public safety (i.e., police, fire, EMS, search and rescue); health/medical; public works; and transportation services.
- Operations planning necessary to ensure effective support services for routine emergency operations and extreme national emergency conditions.
- Development and maintenance of plans and capabilities to provide life-sustaining supplies and services to the affected population, including shelter life support.

6. **Emergency Organization, Planning, and Management**

- Development and maintenance of the infrastructure required to direct and support emergency management activities in the areas of mitigation, preparedness, response, and recovery.
- Coordination of all systems, programs, and operations planning to ensure an integrated response capability.
- Authorities (operational and budgetary), policies, laws, ordinances, agreements, procedures, and personnel required for effective program management and emergency operations.
- Assignment of emergency responsibilities within and external to the emergency management organization.

7. **Hazard Analysis and Mitigation**

- The identification of hazards and the risks to population and property that could result from those hazards.

- The development and support of programs, policies, ordinances, and practices to reduce the likelihood of a life- or property-threatening event occurring, or to lessen the effects of the event should it occur.

8. Training and Exercising

- The development of knowledge and skills required to perform assigned functions and tasks.
- The maintenance and enhancement of individual and system skills, processes, and procedures under simulated emergency conditions.
- The demonstration of relationships and dependencies among and between organizations and functions in an emergency operating environment.

Each of the above functions would have to be performed in the radiological environment that could exist anywhere in the United States after a nuclear attack or radiological incident, and this would be impossible without radiological intelligence. Thus, a key requisite for effective implementation of IEMS in a nuclear attack context is an adequate supply of radiological instruments at the State and local levels.

Chapter 10

REQUIREMENTS FOR RADEF INSTRUMENTS

Radiological defense instrument requirements are based on:

- The current multihazard radiological threat.
- Specific emergency management program standards and criteria that State and local governments must meet to be prepared to meet, in turn, the multihazard radiological threat.
- Identified personnel needed to achieve full capability as specified in the standards and criteria.
- Types of instruments--both existing and under development.
- Characteristics, range, and use of each type of instrument.

In the U.S. today, the 3,450 State and local operational areas are the minimum number of government units that must have a fully developed emergency management capability to achieve the goals of the IEMS. Along with other activities, each of these areas must work toward developing full capability to handle multihazard radiological emergencies. This includes having sufficient radiological instruments on hand.

Each of the 3,450 operational areas in the United States requires radiological instruments for the following five operational functions and three user categories. The basis for the numbers shown under "User Categories" is discussed throughout the following pages of this chapter.

- Functions
    - Direction and Control--Continuity of Government (COG).
    - Attack Response—Multihazard Application.
    - Population Protection--Public and Key Worker Shelter.
    - Post Attack/Incident Recovery Operations.
    - Training.
- User Categories
    1. Radiological Response Team (RRT) members (.104 million).
    2. Radiological Monitors to support:
        - Emergency services personnel (2.805 million).
        - Critical/key workers (19.782 million).
        - Fixed and mobile EOCs (.003 million).
        - Emergency broadcast stations (.003 million).

- Key worker shelter facilities (.020 million).
- Public shelter facilities (.740 million).

3. Training (.003 million jurisdictions).

Instruments for public shelters and key worker shelters contribute to meeting requirements for emergency service personnel, critical/key workers, and post attack recovery and attack response. Instruments for EOCs and emergency broadcast stations satisfy only the Direction and Control/COG function. Since Direction and Control is a continuous function, instruments dedicated for this purpose should not be considered available to meet any other requirement. Estimates of quantities of radiological instruments required to support each function and user category are described below.

DIRECTION AND CONTROL—CONTINUITY OF GOVERNMENT

Direction and control systems provide the facilities, resources, and processes to ensure effective communication and management of information for decisions vital to protection of the population. This function includes instrument requirements to support 3,450 fixed and 3,450 mobile EOCs, one of each for each operational area. In addition, it includes requirements for 2,700 emergency broadcast stations. Instrument requirements for direction and control do not overlap any other function/user group.

	High-Range Dosimeters (HRD)	Intermediate-Range Dosimeters (IRD)	Chargers	Wide-Range Ratemeters
EOCs:				
Fixed	17,250	17,250	6,900	6,900
Mobile	34,500	34,500	34,500	34,500
Subtotal	51,750	51,750	41,400	41,400
Broadcast Station Protection:	5,400	5,400	5,400	5,400
Function Total	**57,150**	**57,150**	**46,800**	**46,800**

Fixed EOCs

The minimum instrument requirements for fixed EOCs above are based on EOC staffing requirements identified in CPG 1-20, Emergency Operating Centers Handbook. The EOC staff is divided into five specific groups:

- Policy group.
- Communications personnel.
- Disaster analysis group.
- Operations group.
- Resource group.

To meet minimum radiological instrumentation support for fixed EOCs, at least one high-range and one intermediate-range dosimeter should be provided to each of the above staffing groups. Since the fixed EOC is a self-supporting entity for direction and control, at least two chargers and two wide-range ratemeters should be available. Providing two of each charger and ratemeter provides for backup in the event of instrument failure. The minimum national EOC radiological instrumentation requirements for fixed EOCs, therefore, are determined as follows:

- High-range dosimeter: Five staff groups x 3,450 EOCs = 17,250.
- Intermediate-range dosimeter: Five staff groups x 3,450 EOCs = 17,250.
- Charger: 2 x 3,450 = 6,900.
- Wide-range ratemeter: 2 x 3,450 = 6,900.

Another concept for determining EOC instrumentation requirements could be considered if each member of the fixed EOC staff were considered an emergency worker. Using this concept, each staff member would require his or her own dosimeter. EOC staffing requirements are shown in Figure 10.

Figure 10

EOC STAFFING REQUIREMENTS

- Director, Emergency Management Agency or Emergency Services
  - Emergency Management Coordinator and Staff
  - Public Information Officer
  - Situation Analysts and Plotters
  - Communications Officer
  - Communications Representatives (including radio and telephone operators)
  - Radiological Defense Officer
  - Warning Officer
  - Procurement Representative

- Police Representative(s)
- Fire Representative(s)
- Public Works/Engineering Representative(s)
- Health/Medical Representative(s)
- Welfare/Shelter Representative(s)
- Utilities Representatives
  - Water
  - Electricity
  - Gas
  - Sanitation

- Resource Representatives
  - Food
  - Housing
  - Transportation
  - Telecommunications
  - Petroleum Products
  - Agriculture

- Representatives of Voluntary Agencies
  - Red Cross
  - Salvation Army
  - Church Groups
  - Radio Amateurs
  - Citizens Band Groups

- State and Federal Representatives

EOC staff size varies, based on the population and resources represented within each operational area and the potential impact of a Population Protection Plan on the resident population. The impact will depend on whether the EOC is located in a potential hazard area or reception area. Recommended Government EOC staff composition (CPG 1-20) for two-shift operations varies from a minimum of 25 to over 126 personnel, based on the representative population for each operational area. Instrument requirements can be estimated on the assumption that the average staff size for EOC operation is the average of the minimum and maximum staffing pattern for two-shift operation. Thus, 126 maximum plus 25 minimum equals 151, with an average EOC staff size of 75.

Each EOC should have, as a minimum, two chargers and two ratemeters (one to provide backup). Total national requirements for fixed EOCs, using these criteria, would be:

- Dosimeters: 3,450 fixed EOCs x 75 staff personnel = 258,750.
- Chargers: 3,450 x 2 = 6,900.
- Ratemeters: 3,450 x 2 = 6,900.

Mobile EOCs

It is assumed that each mobile EOC would consist of 10 staff members drawn from various units of government. Since the composition of the mobile EOC may vary with time, designated mobile EOC representatives should be assigned their instruments in advance. Each member of the mobile EOC is classified as an emergency worker and requires his or her own set of instruments.

10 team members x 3,450 = 34,500 individual dosimeters, chargers, and ratemeters.

Broadcast Station Protection

The instrument complement should provide for two instruments of each type for each station to allow for two 12-hour shift operations.

2 x 2,700 = 5,400 of each type of instrument.

Instruments procured to meet requirements for Direction and Control—Continuity of Government (COG) cannot be used to meet instrument requirements for any of the other four remaining functions due to their singular purpose and continuous use.

ATTACK RESPONSE—MULTIHAZARD APPLICATION

This function includes State and local instrument requirements for emergencies initiated by terrorism, accidental launch, weapons accidents, satellite re-entry, fixed nuclear facilities, transportation, and/or nuclear war. Operational personnel in these situations are Radiological Response Team (RRT) members in each of the 3,450 operational areas and emergency services personnel. Each operational area RRT should be composed of 30 members recruited from public- and private-sector emergency service organizations. The RRT would support the emergency services personnel who would be from first-on-the-scene emergency services organizations.

	High-Range Dosimeters (HRD)	Intermediate-Range Dosimeters (IRD)	Chargers	Wide-Range Ratemeters
103,500 RRT Members	*(103,500)	*(103,500)	*(103,500)	*(103,500)
2,805,014 Emergency Services	2,805,014	2,805,014	561,000	561,000
Function Total	**2,805,014**	**2,805,014**	**561,000**	**561,000**

The above instrument complement provides for the following instrument distribution:

- Since the RRT is composed of 30 members, each team member should be furnished with each type of instrument. Thirty team members x 3,450 operational areas = 103,500 instruments of each type.
- Emergency Services/First Responders:
  - One high-range dosimeter per member of Emergency Services.
  - One intermediate-range dosimeter per member of Emergency Services.
  - One charger per five people.
  - One wide-range ratemeter per five people.

Members of emergency services/first responders are all considered emergency workers. It is estimated that a group of five individuals is the minimum number comprising an operational team. This allows for 24-hour coverage with two 12-hour shifts of two people each, with a third person in reserve for shift rotation and exchange.

Overall instruments required to meet the attack response-multihazard application would be satisfied through procurement of instruments to meet requirements for the population protection function for public and key worker shelters. Day-to-day operational instrument requirements for RRTs and emergency services/first responders are less than the requirements for public and key worker shelters. In

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*Indicates instrument requirements are considered part of overall emergency services requirements. Operational instruments for use by the RRT should be drawn from overall emergency services instrumentation.

addition, all members of emergency services, including RRTs, would be assigned to shelters together with their respective instrument complement. Thus, shelter instrument procurement provides for meeting wide-range instrument needs for radiological emergencies.

POPULATION PROTECTION—PUBLIC AND KEY WORKER SHELTERS

Determination of instruments required to support shelters is based on an analysis of critical/key workers in high hazard areas and the population in: high hazard areas, hazard-reception areas, and low hazard nonreception areas requiring radiological protection in the event of an attack incident. Shelter requirements are based on the use of approximately 740,000 public shelter facilities.

	High-Range Dosimeters (HRD)	Intermediate-Range Dosimeters (IRD)	Chargers	Wide-Range Ratemeters
Key Worker Shelter	170,000	170,000	40,000	40,000
Public Shelter	29,190,000	29,190,000	2,919,000	2,919,000
Function Total	**29,360,000**	**29,360,000**	**2,959,000**	**2,959,000**

Public Shelters

Public shelter facilities can be divided into three categories: existing in place, upgradeable, and expedient.

Area	Category	No. of Shelters	Average Number of Spaces per Shelter
High Hazard	Existing in-place	39,600	1,000
Reception	Existing in-place	95,000	400
	Upgradeable	311,400	500
	Expedient	216,000	100
Low Hazard	Existing in-place	30,600	1,000
Nonreception	Upgradeable	17,000	200
	Expedient	30,000	100
Total		**739,600**	

FEMA publication CPG 2-6.4, Radiation Safety in Shelters, recommends having at least one dosimeter for every 10 occupants of a shelter, plus additional dosimeters for radiological monitors and shelter managers. Shelter managers and radiological monitors are considered emergency workers. Their dosimeter requirements are considered to be satisfied under the above, based on distribution of instruments to individual shelters to cover potential loading. Shelter requirements for ratemeters and chargers are determined based on the assumption that individual groups of 100 shelterees would occupy a designated area of a shelter. Each group of 100 shelterees would require an individual ratemeter and charger. This group of 100 shelters would consist of 10 groups of 10 people each. One dosimeter would be assigned to each group of 10 people for monitoring shelter exposure. To prevent dilution of span of control, it would not be desirable to assign a survey meter to more than 10 groups of 10 shelterees for exposure control purposes. To calculate numbers of instruments required, it is first necessary to calculate potential groups of 100 shelterees:

High-Hazard Reception	39,600 existing in-place shelters x 10 (1,000 spaces : 100)	=	396,000
	95,000 existing in-place shelters x 4 (400 spaces : 100)	=	380,000
	311,400 upgradeable shelters x 5 (500 spaces : 100)	=	1,557,000
	216,000 expedient shelters x 1 (100 spaces : 100)	=	216,000
Low-Hazard Non-Reception	30,600 existing in-place shelters x 10 (1,000 spaces : 100)	=	306,000
	17,000 upgradeable shelters x 2 (200 spaces : 100)	=	34,000
	30,000 expedient shelters x 1 (100 spaces : 100)	=	30,000
	Total potential groups of 100 shelterees		**2,919,000**

The following number of instruments, therefore, should be made available to each potential group of 100 shelterees:

• High-range dosimeter (one per 10 people):	10 x 2,919,000 = 29,190,000.
• Intermediate-range dosimeter (one per 10 people):	10 x 2,919,000 = 29,190,000.
• Charger (one per 100 people):	1 x 2,919,000 = 2,919,000.
• Wide-range ratemeter (one per 100 people):	1 x 2,919,000 = 2,919,000.

The above requirements are based on the assumption that 20 percent of the population would not evacuate from a high hazard area under a relocation plan. This would generate a requirement to shelter in-place within the high hazard area. Reception areas provide shelter for the resident population and evacuees through existing in-place shelters, upgradeable shelters, and expedient shelters. Within the reception area, it is assumed that, based on population distribution, there would be a requirement for expedient shelter.

In low hazard nonreception areas, population is geographically dispersed over a wide area. It is assumed that in-place shelters would be supplemented by a combination of upgradeable and expedient shelters. The above requirements reflect the fact that population distribution within individual shelters would be skewed with regard to capacity. It is important to recognize that these numbers represent best estimates of instrument requirements in the absence of developed State and local emergency operations plans and radiological defense annexes that would identify more exact requirements for radiological instruments.

Critical workers (discussed under "Post Attack/Incident Recovery Operations") would be housed in public and key worker shelters and would provide radiological support to public fallout shelters. In addition, critical workers would provide radiological support for post attack recovery operations. The early post attack in-shelter environment generates the need for high-range dosimeters and ratemeters to take readings within the shelter. Out-of-shelter post attack recovery operations generate the requirement for intermediate-range dosimeters and wide-range ratemeters.

Key Worker Shelter

The May 1984 report "Methods and Procedures to Specify Key Worker Blast Shelter (KWBS) Location and Requirements, TR-009-84" specifies the number and location of blast shelter spaces for key workers on an industry-by-industry basis for the Protection of Industrial Capability (PIC) program. The report identifies which industries provide direct and indirect inputs to the production of critical commodities; determines levels of production by industry required to support the population, manage a crisis, and maintain national defense; determines the locations in which critical production could take place; determines the amount of production that would require blast sheltering and different levels of industrial protection; and determines the number of key workers involved in critical production and the minimum number of blast shelter spaces required to ensure continued critical production.

To show the relationship between blast shelter requirements in the report, two scenarios were selected for the analysis—no mobilization and mobilization. The no-mobilization scenario represents lower estimates of requirements associated with a nuclear attack threat preceded by minimal war-fighting. The mobilization scenario represents upper estimates associated with a nuclear attack threat preceded by a large-scale, multi-theater conventional war.

In the no-mobilization scenario, industries tended to be producers of end items within the food, medical services, armaments, communications equipment, and energy sectors. In the mobilization scenario, this list is expanded to include some producers of intermediate goods used in defense production and expansion such as primary metals, electronic components, industrial machinery, machine tools, construction supplies, and metals mining.

In most industries, after critical production was accounted for, there was still residual non-hazard area capability available for production. To minimize production in hazard areas, it was assumed that critical production could be shifted from hazard-area facilities to residual non-hazard area facilities in the same industry. It was determined that location shifts had relatively minor effects on the amount of production at risk. After location shifts were taken into account, 53 percent of the critical production was at risk in the no-mobilization scenario (as opposed to 66 percent before shifts), and 56 percent was at risk in the mobilization scenario (as opposed to 60 percent before shifts).

In the no-mobilization scenario, 56 percent of the production at risk was for population support, 32 percent was for defense, 8 percent was for crisis management, and 4 percent was for defense investment. In the mobilization scenario, defense production at risk increased substantially and accounted for 50 percent of the total production at risk, population support accounted for 33 percent of the production at risk, defense investment accounted for 12 percent, and crisis management for only 5 percent.

In the no-mobilization scenario, it was concluded that shelter space requirements should be no larger than 1.9 million (1,884,100 spaces). Initial estimates, based on further study, indicate that the baseline figure will be 1.7 million spaces, which is the number used in this document. It is estimated that approximately 20,000 shelter facilities would be required to shelter the 1.7 million key workers in the hazard area. The no-mobilization scenario is the basis for determining instrument requirements for key workers under the assumption that during mobilization, additional instrument support could be factored in to defense mobilization production to meet deficient instrument requirements.

Instrument distribution would provide one high-range and one intermediate-range dosimeter for every 10 workers in shelter. Two chargers and two wide-range ratemeters should be provided to have a backup capability for instrument failure. This would provide minimal radiological protection capabilities. When these workers emerged from shelter, they would require individual dosimetry to conduct their respective operations. Therefore, where actual instruments were deployed in a local community, there would be a requirement to adjust dosimetry between public shelters and key worker shelters based on individually identified mission requirements.

Hazard-Area Shelter Facilities = 20,000
1.7 million spaces (minimum no-mobilization)

- High-range dosimeter (one per 10 people): $\frac{1,700,000}{10} = 170,000$
- Intermediate-range dosimeter (one per 10 people) $\frac{1,700,000}{10} = 170,000$
- Charger: 20,000 x 2 = 40,000
- Wide-range ratemeter: 20,000 x 2 = 40,000

Population Protection

Public and key worker shelters drives the largest requirement for dosimeters. Procurement of instruments for this function would also satisfy all instrument requirements for the following functions (with the exception of chargers and wide-range ratemeters): Attack Response-Multihazard Application, Post Attack/Incident Recovery Operations, and Training. The total number of chargers and wide-range ratemeters required to meet the function of Post Attack/Incident Recovery Operations exceeds the amount required for Population Protection.

POST ATTACK/INCIDENT RECOVERY OPERATIONS

Post Attack/Incident Recovery Operations requirements are based on an analysis of private-sector industries. They would provide critical/key workers for essential population support services and direct defense needs. They would also provide emergency services professional and volunteer personnel to perform vital government services. Examples of critical/key workers are people employed in the manufacture of pharmaceutical preparations; medical, chemical, and biological products; soaps; health and medical supplies; semiconductors and other electrical components; food products; etc. Examples of emergency services personnel are professional and volunteer firefighters, police officers, emergency medical technicians, public works employees, etc.

	High-Range Dosimeters (HRD)	Intermediate-Range Dosimeters (IRD)	Chargers	Wide-Range Ratemeters
Critical/Key Workers	19,782,000	19,782,000	3,956,400	3,956,400
Emergency Services	2,805,014	2,805,014	561,000	561,000
Function Total	**22,587,014**	**22,587,014**	**4,517,400**	**4,517,400**

During the very early post attack period, when radiation exposure (dose) rates would be high but decaying rapidly, field operations could be assumed to be limited to missions of great urgency. The number of personnel engaged in operations entailing high radiation exposure would be relatively small. However, radiation exposures could increase rapidly during the performance of the mission, necessitating frequent measurement and evaluation. Persons engaged in these early operations would likely be those possessing specific skills. Their services would be needed during later recovery periods to perform or direct necessary functions for post attack recovery operations. The category of critical/key workers encompasses individuals employed in activities in hazard and reception areas considered essential to:

- Produce, store, distribute, and dispose of key commodities.
- Rescue.
- Sustain the population.
- Decontaminate streets, buildings, and areas.
- Support a vital defense posture.
- Maintain civil law and order.
- Preserve or efficiently resume production after cessation of the conflict period.
- Firefighting.
- Mass feeding and distribution of food and emergency supplies.
- Maintenance of government-operated public services such as power, water, and sewage systems and streets and roads.

For purposes of determining total radiological instrument requirements, numbers of critical/key workers, emergency services/first responders, etc., are detailed in Figure 9 (Chapter 8).

During the later periods of recovery, more personnel would work in contaminated areas, trying to restore essential life support services. Although exposure (dose) rates would be lower, they would also vary greatly as a worker moved from area to area or as changing work locations involved greater or less shielding from the ambient radiation field. Thus, to avoid unnecessary radiation injury and incapacitation of personnel and for programmed continuity of skilled functions to be possible, it would be imperative that the radiation exposures (doses) of emergency/critical workers be measured and recorded.

Unsheltered emergency survival and recovery functions performed by critical/key workers, while a significant radiation hazard still existed, would be initiated from public shelters or individual locations. Each operational unit could be different and would require its own supply of dosimeters, ratemeters, and chargers. The number of chargers and ratemeters required would be dependent on the size of the operational group and the number of vehicles assigned to the group. Post Attack/Incident Recovery Operations drives the largest requirement for ratemeters and chargers. Instrument requirements for post attack recovery operations are based on the following:

- High-range dosimeter: 1 per individual.
- Intermediate-dosimeter: 1 per individual.
- Charger: 1 per 5 individuals.
- Ratemeter: 1 per 5 individuals.

A group of five individuals is considered the minimum number of individuals who would comprise an operational team. This would allow for 24-hour coverage with two 12-hour shifts of two people each, with a third person in reserve for shift rotation and exchange.

Because a nuclear attack could seriously contaminate vast areas of the Nation with radioactive fallout, personnel performing emergency community services would work under such varied conditions of radiation exposure that estimates of exposures (doses) based on general area monitoring would not be valid. To avoid overexposure of specially trained emergency services personnel, auxiliaries or individual survivors working under the direction of regulars would be needed to perform many emergency functions. Instruments would be required to support these functions. These auxiliaries and instruments would be drawn from public shelter.

Areas subject to damage from blast and thermal effects and heavy contamination cannot be known in advance. The total number of dosimeters that might be needed by a particular service cannot reasonably be distributed pre-attack. A large portion of the field operations requiring instrument support would be performed during recovery when transportation of instruments over short distances might be feasible. Instruments would be strategically dispersed in State and local stockpiles at relatively safe distances from probable targets. To the extent feasible, instruments allocated to State and local jurisdictions primarily for use in Post Attack/Incident Recovery Operations should be stored in or near shelters or relocation sites.

TRAINING

To implement a national multihazard radiological emergency training program, instrument training sets are required. Training is required nationwide in State and local jurisdictions. Training instruments should be configured in specialized sets and made available for each of the 3,450 operational areas, Metropolitan and State Emergency Services Training Academies, and individual State and Federal Agencies. A float stock of instruments to maintain deployed training instruments is also needed. A numerical detail of these requirements follows:

52	50 State and 2 trust territory State Operational Areas
3,398	Local Operational Areas
1,500	Metropolitan and State Emergency Services Training Academies/various State and Federal agencies
6,000	
+ 1,000	float stock
7,000	training instrument sets (basic requirement)

Based on an average class size of 30 students, each training instrument set should be composed of 50 low-range dosimeters, five chargers, 30 high-range dosimeters, 30 intermediate-range dosimeters, and 15 wide-range ratemeters. This complement of instruments would provide low-range dosimeters to monitor radiation exposure for each of the 30 students and 20 low-range dosimeters for obtaining actual readings from radioactive sources used in training demonstrations. Each student would have a high- and intermediate-range dosimeter for classroom use. One ratemeter would be shared by each group of two students. Therefore, total training instrument requirements are as follows:

● Low-range dosimeters:	50 x 7,000	= 350,000.
● High-range dosimeters:	30 x 7,000	= 210,000.
● Intermediate-range dosimeters:	30 x 7,000	= 210,000.
● Chargers:	5 x 7,000	= 35,000.
● Wide-range ratemeters:	15 x 7,000	= 175,000.

The low-range dosimeter would be used to monitor students and to obtain actual readings from radioactive sources used in training exercises. Although training instruments have a high rate of attrition, they are considered in meeting requirements for the community population protection shelter function. Although existing instruments are on hand for training, all of these are more than 20 years old and will, therefore, require eventual replacement. In addition, there are some inherent technical problems with the existing low-range dosimeters in the inventory that cannot be fixed.

SUMMARY OF INSTRUMENT STATUS AND REQUIREMENTS

Attack preparedness requires the largest number of instruments, many of which can be used as backup for the most extreme conditions of other types of radiological emergencies, such as accidental launch or peacetime terrorist incidents. Attack preparedness requirements, therefore, represent total requirements for basic emergency response instruments. Smaller quantities of more specialized equipment not discussed in this report are also required for the most probable types of peacetime emergencies.

Figures 11 through 13 on the following pages summarize the results of this study. It should be noted that quantities of instruments required are estimates. Only a portion of State and local planning activities have been completed, and estimates of instruments required depend on State and local plans for using radiological instruments in the event of a nuclear attack. For example, States and local areas need to decide whether to distribute their instruments to shelters in high hazard areas. In cases where a decision was made to stock shelters in high hazard areas, then further decisions would have to be made as to whether instruments would be issued to shelterees, pre-located in the shelter spaces, made available to accompany evacuees, etc. Without this detailed information from States and local areas, quantities of instruments required as stated in this document represent the best estimates currently available in the absence of completed Emergency Operations Plans, including Radiological Defense Annexes, for all State and local jurisdictions.

Current Status of Radiological Equipment Inventory

Figure 11, Distribution of RADEF Equipment, provides a numerical detail of the current disposition of 32 different types of radiological equipment. It indicates quantities of each item procured between 1955 and 1985, quantities that have become obsolete or that have been lost through attrition, and quantities still available for distribution. Figure 11 also provides total quantities of each type of instrument currently included in the inventories of State governments and Federal Agencies; the Federal stockpile; and the inventories of other users (including FEMA facilities, contract activities, and foreign countries).

Figure 12, Inventory of Selected Radiological Defense Instruments Issued for Operational Use, shows the distribution of several types of radiological equipment by Federal Region and individual State or territory.

Together, these two figures provide detailed information on the existing inventory of radiological equipment.

Radiological Instrument Requirements

Figure 13, Summary of Radiological Defense Instrument Requirements, reflects quantities of instruments required for functional and user categories as described in this chapter. It should be noted that the net total for each instrument type does not include quantities shown in parentheses because these are included in other user categories. However, this summary does establish that current shortfalls are high for five major categories of radiological instruments. In the best case (low-range dosimeters), the current radiological instrument inventory meets only 30 percent of the projected net requirement. In the worst case (intermediate-range dosimeters), the current national inventory meets only a scant one percent of the projected net requirement. Thus, current shortfalls in the five most essential types of radiological defense instruments range from 71 to 99 percent.

Figure 11

DISTRIBUTION OF RADEF EQUIPMENT
(January 1985)

						Distribution			
No.	Item	Procurement[1] FY 55-85	Obsolete Disposition	Loss thru Attrition	Remainder Available for Distribution	State Inventory	Federal Inventory	Federal Agencies	Various Users[2]
CDV-104	Cesium Capsules	96	-0-	-0-	96	50	46	-0-	-0-
CDV-138	Training Dosimeter	221,866	168	119,259	102,439	79,945	6,649	7,960	7,885
CDV-457	Demonstration Unit	3,576	1,058	-0-	2,518	2,518	-0-	-0-	-0-
CDV-700	Low-Range Survey Meter	452,558	57,343	41,430	353,785	295,581	•8,988	24,440	24,776
CDV-705	Loudspeaker for CDV-700	10,000	-0-	1,933	8,067	6,951	1,069	32	15
CDV-710	Medium-Range Survey Meter	170,750	170,750	-0-	-0-	-0-	-0-	-0-	-0-
CDV-711	Remote Sensor Meter (Blast)	600	200	-0-	400	224	-0-	10	166
CDV-715	High-Range Survey Meter	567,475	25,759	57,782	483,934	460,712	10,549	12,593	80
CDV-717	Remote Reading Survey Meter	100,100	-0-	9,226	90,874	83,801	5,443	1,028	602
CDV-720	High-Range Survey Meter	113,231	44,440	7,606	61,185	38,936	18,190	2,675	1,384
CDV-730	Dosimeter (0-20R)	168,500	221	54,329	113,950	97,344	-0-	12,975	3,631
CDV-736	Dosimeter (0-2R)	500	-0-	43	457	49	319	53	36
CDV-740	Dosimeter (0-100R)	162,950	101	49,393	113,456	61,403	533	39,780	11,740
CDV-742	Dosimeter (0-200R)	3,117,201	3,288	552,358	2,561,555	2,108,701	323,238	79,203	50,413
CDV-746	Dosimeter (0-600R)	500	2	48	450	49	319	54	28
CDV-750	Dosimeter Charger	515,032	38,977	63,819	412,236	378,854	246	27,480	5,656
CDV-756	Dosimeter Charger	500	-0-	44	456	49	319	52	36
CDV-757	Barrier Shielding Demonstrator	81	1	-0-	80	55	25	-0-	-0-
CDV-760	Phosphate Glass Dosimeter	80,000	80,000	-0-	-0-	-0-	-0-	-0-	-0-
CDV-770	Phosphate Glass Charger	153	153	-0-	-0-	-0-	-0-	-0-	-0-
CDV-781	Aerial Survey Meter	1,250	-0-	-0-	1,250	975	59	38	178
CDV-782	Radioactive Source (Cesium)	1,440	-0-	-0-	1,440	870	570	-0-	-0-
CDV-784	Radioactive Source (Cobalt)	3,489	1,779	-0-	1,710	1,710	-0-	-0-	-0-
CDV-786	Radioactive Source (Cobalt)	1,000	987	-0-	13	13	-0-	-0-	-0-
CDV-787	Comparison Standard	60,000	60,000	-0-	-0-	-0-	-0-	-0-	-0-
CDV-788	Handling Tongs	7,560	33	-0-	7,527	6,455	1,000	60	12
CDV-790	Calibration Unit	61	-0-	-0-	61	50	11	-0-	-0-
CDV-791	Lead Container (Small)	4,490	1,208	-0-	3,282	2,593	575	-0-	114
CDV-792	Lead Container (Medium)	4,489	1,208	-0-	3,281	2,593	542	-0-	146
CDV-793	Calibration Unit[3]	20	20	-0-	-0-	-0-	-0-	-0-	-0-
CDV-794	Calibration Unit	74	7	-0-	67	53	6	3	5
CDV-795	Calibration Unit	10	10	-0-	-0-	-0-	-0-	-0-	-0-
	TOTAL	**5,769,552**	**487,713**	**957,270**	**4,324,569**	**3,630,534**	**378,696**	**208,436**	**106,903**

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1. Adjusted to reflect actual quantity received.
2. FEMA facilities, contract activities, foreign countries.
3. Includes CDV-785 radioactive source.

Figure 12

INVENTORY OF SELECTED RADIOLOGICAL DEFENSE INSTRUMENTS ISSUED FOR OPERATIONAL USE

(January 1985)

Area	Survey Meter				Dosimeter Charger	Dosimeter				Loud Speaker	Remote	Aerial Survey Meter	Barrier Shielding Demon-strator
	Low-Range	High-Range	High-Range with Remote Capability	High-Range		Low-Range Training	High-Range						
	CDV-700	CDV-715	CDV-717	CDV-720	CDV-750	CDV-138	CDV-730	CDV-740	CDV-742	CDV-705	CDV-711	CDV-781	CDV-757
TOTAL	**295,581**	**460,712**	**83,801**	**38,936**	**378,854**	**79,945**	**97,344**	**61,403**	**2,108,701**	**6,951**	**224**	**975**	**287**
Region 1	**16,916**	**26,578**	**5,865**	**1,960**	**22,475**	**5,463**	**6,268**	**4,024**	**137,840**	**561**	**12**	**33**	**19**
Connecticut	3,123	5,157	1,356	523	4,468	1,762	1,694	1,261	31,520	120	2	11	0
Maine	1,969	3,293	856	75	2,695	550	950	400	13,200	62	5	7	10
Massachusetts	6,522	11,514	2,321	1,006	9,395	2,124	2,016	1,092	68,964	190	3	10	0
New Hampshire	3,120	3,503	760	100	3,082	400	768	538	11,232	110	1	1	8
Rhode Island	2,182	3,111	572	256	2,835	627	840	733	12,924	79	1	4	1
Vermont	3,120	3,503	760	100	3,082	400	768	538	11,232	110	1	1	8
Region 2	**45,166**	**66,549**	**4,913**	**8,934**	**58,498**	**8,777**	**13,996**	**5,425**	**307,319**	**84**	**27**	**84**	**2**
New Jersey	5,872	18,594	2,475	1,943	10,257	1,739	4,179	2,448	52,800	10	2	19	1
New York	37,254	45,155	1,763	6,841	45,151	6,713	8,717	2,877	235,109	64	24	59	1
Puerto Rico	2,040	2,800	675	150	3,090	325	1,100	100	19,410	10	1	6	0
Virgin Islands[1]													
Region 3	**31,097**	**51,908**	**9,073**	**3,147**	**35,369**	**5,306**	**7,150**	**2,184**	**180,085**	**911**	**8**	**50**	**34**
Delaware[2]													
Dist. of Columbia[2]													
Maryland	3,779	9,680	1,403	211	4,331	1,041	717	384	15,443	200	6	14	32
Pennsylvania	21,038	28,190	5,500	2,120	19,269	2,261	5,618	1,340	98,776	409	1	2	1
Virginia	3,780	8,597	450	39	6,070	1,250	0	0	39,660	221	0	27	0
West Virginia	2,500	5,441	1,720	777	5,699	754	815	460	26,206	81	1	7	1
Region 4	**39,460**	**68,103**	**12,919**	**6,135**	**53,375**	**12,627**	**14,198**	**5,960**	**265,442**	**875**	**26**	**156**	**124**
Alabama	6,300	10,420	1,980	550	6,064	1,650	1,250	1,000	39,420	140	7	20	56
Florida	6,881	10,824	1,836	805	9,077	3,097	2,800	950	47,320	200	5	21	0
Georgia	5,349	6,850	59	696	5,699	930	300	381	29,868	0	5	20	20
Kentucky	6,215	7,549	1,920	1,790	7,602	1,725	1,700	910	25,740	113	0	24	1
Mississippi	810	1,075	1,500	715	1,500	550	1,650	885	10,585	80	4	14	1
North Carolina	5,300	13,800	2,300	500	8,900	2,600	1,600	185	41,200	135	2	20	45
South Carolina	2,832	8,928	1,429	535	7,864	432	1,189	266	34,574	79	2	17	0
Tennessee	5,773	8,657	1,895	544	6,669	1,643	3,709	1,383	36,735	128	1	20	1

Region 5	**45,279**	**79,648**	**17,173**	**4,567**	**66,469**	**14,854**	**18,557**	**13,894**	**429,479**	**1,202**	**57**	**183**	**26**
Illinois	9,131	16,426	4,043	306	13,307	4,395	900	1,534	94,159	100	35	28	23
Indiana	4,566	11,085	2,552	586	6,842	1,247	2,316	1,386	38,142	220	3	23	0
Michigan	7,000	12,964	1,870	740	14,150	3,500	1,500	1,500	104,000	320	8	33	1
Minnesota	7,582	12,960	1,964	418	9,063	1,661	2,450	624	38,221	1	2	30	1
Ohio	8,750	14,900	4,550	1,876	12,528	1,380	6,380	5,000	100,800	380	1	46	0
Wisconsin	8,250	11,313	2,194	641	10,579	2,671	5,011	3,850	54,157	181	8	23	1
Region 6	**25,550**	**41,242**	**12,148**	**5,049**	**41,480**	**7,946**	**7,580**	**5,742**	**242,078**	**1,134**	**17**	**127**	**5**
Arkansas	2,538	6,054	1,583	488	3,976	978	1,062	600	14,578	200	1	16	0
Louisiana	3,675	5,650	1,798	880	5,430	1,350	1,500	760	39,000	202	4	9	1
New Mexico	2,252	4,280	1,040	1,400	3,540	510	1,700	1,060	16,500	185	3	10	2
Oklahoma	4,592	6,997	2,100	593	6,371	1,260	584	2,842	32,100	142	4	14	0
Texas	12,493	18,261	5,627	1,688	22,163	3,848	2,734	480	139,900	405	5	78	2
Region 7	**19,131**	**35,084**	**6,908**	**2,816**	**29,404**	**8,342**	**5,863**	**6,453**	**136,965**	**921**	**12**	**92**	**40**
Iowa	3,989	6,460	1,956	619	6,523	1,258	185	1,922	28,338	502	0	18	39
Kansas	5,198	9,670	840	11	7,901	2,250	1,790	1,570	34,991	198	4	14	1
Missouri	5,600	11,216	2,508	845	9,050	2,175	2,600	500	51,000	151	4	25	0
Nebraska	4,344	7,738	1,604	1,341	5,930	2,659	1,288	2,461	22,636	70	4	35	0
Region 8	**23,326**	**24,300**	**4,912**	**1,540**	**16,838**	**3,266**	**3,425**	**3,429**	**65,392**	**266**	**16**	**69**	**16**
Colorado	614	3,195	1,396	157	2,746	250	350	182	16,388	100	1	18	1
Montana	14,053	4,801	755	272	3,402	159	159	736	8,956	0	4	14	1
North Dakota	2,477	4,360	920	456	2,624	487	686	528	9,490	39	1	12	1
South Dakota	1,857	4,552	900	196	3,184	546	559	482	12,080	40	3	3	12
Utah	2,592	4,000	326	175	2,897	939	1,000	900	10,478	35	6	11	0
Wyoming	1,733	3,392	615	284	1,985	885	671	601	8,000	52	1	11	1
Region 9	**24,764**	**32,640**	**5,938**	**2,741**	**30,385**	**10,054**	**15,677**	**11,287**	**220,754**	**796**	**37**	**104**	**18**
Arizona	2,773	3,934	417	94	2,937	951	560	705	16,661	91	4	23	1
California	18,462	24,332	4,829	2,384	23,626	8,328	14,417	9,782	188,816	652	25	57	14
Hawaii	1,426	2,004	666	119	1,753	525	700	800	11,139	53	8	9	1
Nevada	2,103	2,370	26	144	2,069	250	0	0	4,138	0	0	15	2
American Samoa													
Guam[3]													
Region 10	**24,892**	**34,660**	**3,952**	**2,047**	**24,561**	**3,310**	**4,630**	**3,005**	**123,347**	**201**	**12**	**77**	**3**
Region 10[3]	1,537	1,460			1,000				7,000	0	0	0	
Alaska	2,101	3,219	348	174	1,846	261	125	342	9,108	31	2	6	1
Idaho	5,240	6,515	738	322	4,905	344	469	323	25,667	0	5	11	1
Oregon	4,346	7,856	1,096	546	6,128	1,105	906	785	27,739	20	2	25	0
Washington	11,668	15,610	1,770	1,005	10,682	1,600	3,130	1,555	53,833	150	3	35	1

1. Serviced by Puerto Rico.
2. Serviced by Maryland.
3. Held at Federal Center for eventual distribution.

Figure 13

SUMMARY OF RADIOLOGICAL DEFENSE INSTRUMENT REQUIREMENTS

Functions and User Categories	High-Range Dosimeters	Intermediate-Range Dosimeters	Low-Range Dosimeters	Chargers	Wide-Range Ratemeters
● Direction and Control/Continuity of Government					
- Fixed/Mobile EOC (.003 million facilities)	51,750	51,750		41,400	41,400
- Broadcast Facilities (.003 million facilities)	5,400	5,400		5,400	5,400
● Attack Response/Multihazard Application					
- Emergency Services Personnel (2.805 million)	(2,805,014)	(2,805,014)		(561,000)	(561,000)
- RRT Members (.107 million)	(103,500)	(103,500)		(103,500)	(103,500)
● Population Protection/Public and Key Worker Shelters					
- Key Worker Shelters (.030 million facilities	170,000	170,000		40,000	40,000
- Public Shelters (.739 million facilities)	29,190,000	29,190,000		2,919,000	2,919,000
● Postattack/Incident Recovery Operations					
- Critical/Key Workers (19.782 million)	(19,782,000)	(19,782,000)		1,643,400	1,643,400
- Emergency Services Personnel (2.805 million)					
● Training	(210,000)	(210,000)	350,000	(35,000)	(105,000)
Total Net Requirement	29,417,150 (100%)	29,417,150 (100%)	350,000 (100%)	4,649,200 (100%)	4,649,200 (100%)
Current Inventory*	2,562,005 (9%)	227,863 (1%)	102,439 (29%)	412,236 (8%)	636,000 (14%)
Current Shortfalls	**26,855,145 (91%)**	**29,189,287 (99%)**	**247,561 (71%)**	**4,236,964 (92%)**	**4,013,200 (86%)**

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* All these instruments will require eventual replacement. Training instruments have a high rate of attrition, and some have inherent technical problems that cannot be fixed. In addition, the inventory does not reflect other special purpose instruments for aerial radiological monitoring, source sets for training, special EOC and government preparedness equipment, and equipment for maintenance and calibration of the inventory.