

AD-A175 839

NEUTRON EXPOSURE FOR DOD NUCLEAR TEST PERSONNEL(U)

1/1

SCIENCE APPLICATIONS INTERNATIONAL CORP MCLEAN VA

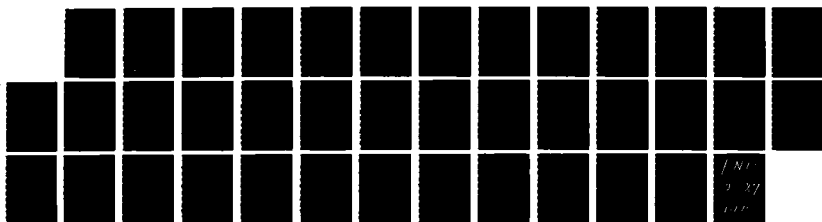
J GOETZ ET AL 15 AUG 85 SAIC-85/1814 DNA-TR-84-405

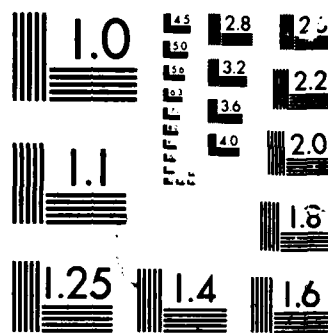
UNCLASSIFIED

DNA001-84-C-0351

F/G 6/18

NL





AD-A175 839

7.2

DNA-TR-84-405

NEUTRON EXPOSURE FOR DOD NUCLEAR TEST PERSONNEL

**J. Goetz
J. Klemm
C. Thomas
R. Weitz
Science Applications International Corporation
P. O. Box 1303
McLean, VA 22101-1303**

15 August 1985

Technical Report

CONTRACT No. DNA 001-84-C-0351

Approved for public release;
distribution is unlimited.

THIS WORK WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B350084466 U99QMXMH00012 H2590D.

**Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305-1000**

DTIC FILE COPY

**DTIC
ELECTED
JAN 7 1987
A**

87

1 0 0

Destroy this report when it is no longer needed. Do not return to sender.

PLEASE NOTIFY THE DEFENSE NUCLEAR AGENCY,
ATTN: STTI, WASHINGTON, DC 20305-1000, IF YOUR
ADDRESS IS INCORRECT, IF YOU WISH IT DELETED
FROM THE DISTRIBUTION LIST, OR IF THE ADDRESSEE
IS NO LONGER EMPLOYED BY YOUR ORGANIZATION.



DISTRIBUTION LIST UPDATE

This mailer is provided to enable DNA to maintain current distribution lists for reports. We would appreciate your providing the requested information.

- ☐ Add the individual listed to your distribution list.
- ☐ Delete the cited organization/individual.
- ☐ Change of address.

NAME: _____

ORGANIZATION: _____

OLD ADDRESS

CURRENT ADDRESS

TELEPHONE NUMBER: () _____

SUBJECT AREA(s) OF INTEREST:

DNA OR OTHER GOVERNMENT CONTRACT NUMBER: _____

CERTIFICATION OF NEED-TO-KNOW BY GOVERNMENT SPONSOR (if other than DNA):

SPONSORING ORGANIZATION: _____

CONTRACTING OFFICER OR REPRESENTATIVE: _____

SIGNATURE: _____

AD-A175839

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188 Exp. Date: Jun 30, 1986	
1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY N/A since Unclassified			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A since Unclassified					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) SAIC-85/1814			5. MONITORING ORGANIZATION REPORT NUMBER(S) DNA-TR-84-405		
6a. NAME OF PERFORMING ORGANIZATION Science Applications International Corporation		6b. OFFICE SYMBOL (if applicable)	7a. NAME OF MONITORING ORGANIZATION Director Defense Nuclear Agency		
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 1303 McLean, VA 22102-1303			7b. ADDRESS (City, State, and ZIP Code) Washington, DC 20305-1000		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DNA 001-84-C-0351		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO. 62715H	PROJECT NO. U99QMXM	TASK NO. H
			WORK UNIT ACCESSION NO. DH008529		
11. TITLE (Include Security Classification) NEUTRON EXPOSURE FOR DOD NUCLEAR TEST PERSONNEL					
12. PERSONAL AUTHOR(S) Goetz, J., Klemm, J., Thomas, C., Weitz, R.					
13a. TYPE OF REPORT Technical		13b. TIME COVERED FROM 840615 TO 841215		14. DATE OF REPORT (Year, Month, Day) 850815	
15. PAGE COUNT 40					
16. SUPPLEMENTARY NOTATION This work was sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B350084466 U99QMXMH00012 H2590D.					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD GROUP SUB-GROUP			Nuclear Test Personnel Review		
18 3			Neutron Dose		
6 18			Radiation Transport		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
Neutron doses for DoD units/projects that participated in atmospheric nuclear test programs are assessed using computer codes ATR and ANISN. Units/projects whose personnel are identified as having received a neutron dose of at least 1 mrem are listed by operation and shot. Of the several thousand units/projects screened, 160 are identified as having received a free-field neutron exposure exceeding 1 mrem. Of these, approximately 75 percent are aircrews with the remainder being ground-based units, either scientific projects or military observer/maneuver units.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL Betty L. Fox			22b. TELEPHONE (Include Area Code) (202) 325-7042		22c. OFFICE SYMBOL DNA/STTI

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement

MULTIPLY → BY → TO GET
TO GET ← BY ← DIVIDE

angstrom	1.000 000 X E -10	meters (m)
atmosphere (normal)	1 013 25 X E +2	kilo pascal (kPa)
bar	1 000 000 X E +2	kilo pascal (kPa)
barn	1.000 000 X E -28	meter ² (m ²)
British thermal unit (thermochemical)	1.054 350 X E +3	joule (J)
calorie (thermochemical)	4 184 000	joule (J)
cal (thermochemical)/cm ²	4 184 000 X E -2	mega joule/m ² (MJ/m ²)
curie	3 700 000 X E +1	*giga becquerel (GBq)
degree (angle)	1.745 329 X E -2	radian (rad)
degree Fahrenheit	$t_F = (t_C + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 X E -19	joule (J)
erg	1.000 000 X E -7	joule (J)
erg/second	1.000 000 X E -7	watt (W)
foot	3.048 000 X E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3 785 412 X E -3	meter ³ (m ³)
inch	2.540 000 X E -2	meter (m)
jerk	1 000 000 X E +9	joule (J)
joule/kilogram (J/kg) (radiation dose absorbed)	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 X E +3	newton (N)
kip/inch ² (ksi)	6 894 757 X E +3	kilo pascal (kPa)
ktop	1.000 000 X E +2	newton-second/m ² (N-s/m ²)
micron	1 000 000 X E -6	meter (m)
mil	2.540 000 X E -5	meter (m)
mile (international)	1.609 344 X E +3	meter (m)
ounce	2.834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 X E -1	newton-meter (N-m)
pound-force/inch	1 751 268 X E +2	newton/meter (N/m)
pound-force/foot ²	4.788 026 X E -2	kilo pascal (kPa)
pound-force/inch ² (psi)	6 894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 X E -1	kilogram (kg)
pound-mass-foot ² (moment of inertia)	4.214 011 X E -2	kilogram-meter ² (kg-m ²)
pound-mass/foot ³	1 601 846 X E +1	kilogram/meter ³ (kg/m ³)
rad (radiation dose absorbed)	1.000 000 X E -2	*Gray (Gy)
roentgen	2 579 760 X E -4	coulomb/kilogram (C/kg)
shake	1 000 000 X E -8	second (s)
slug	1.459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 X E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s

**The Gray (Gy) is the SI unit of absorbed radiation.

TABLE OF CONTENTS

Section	Page
CONVERSION TABLE	iii
LIST OF ILLUSTRATIONS	v
LIST OF TABLES	v
1 INTRODUCTION AND SUMMARY	1
2 ISODOSE CONTOURS	2
2.1 CONTINENTAL ISODOSE CONTOURS	2
2.2 OCEANIC ISODOSE CONTOURS	3
3 DOD PERSONNEL RECEIVING NEUTRON DOSES	9
3.1 CONTINENTAL OPERATIONS	9
3.2 OCEANIC OPERATIONS	16
4 CONCLUSIONS	20
5 LIST OF REFERENCES	21

✓

By _____

Distribution _____

Availability _____

Initial entry _____

Initial _____

A1



LIST OF ILLUSTRATIONS

Figure		Page
1	Neutron isodose contours for continental detonations.	4
2	Neutron isodose contours for oceanic detonations-surface bursts.	6
3	Neutron isodose contours for oceanic detonations-air bursts.	8

LIST OF TABLES

Table		Page
1	DoD personnel receiving a neutron dose at Operation BUSTER-JANGLE.	10
2	DoD personnel receiving a neutron dose at Operation TUMBLER-SNAPPER.	10
3	DoD personnel receiving a neutron dose at Operation UPSHOT-KNOTHOLE.	11
4	DoD personnel receiving a neutron dose at Operation TEAPOT.	12
5	DoD personnel receiving a neutron dose at Operation PLUMBBOB.	14
6	DoD personnel receiving a neutron dose at Operation HARDTACK II.	15
7	DoD personnel receiving a neutron dose at Operation DOMINIC II.	15
8	DoD personnel receiving a neutron dose at Operation REDWING.	18
9	DoD personnel receiving a neutron dose at Operation HARDTACK I.	19

SECTION 1

INTRODUCTION AND SUMMARY

A method is developed that allows each participating project or unit in the US atmospheric nuclear testing program to be rapidly screened to determine whether exposure to neutron radiation contributed significantly to an individual's total dose. The most important parameters required are the neutron environment generated by a particular detonation and the participant's distance from the detonation. Knowledge of other factors such as personnel posture at the time of detonation (e.g., standing in the open, crouched in a trench, or in an aircraft) permit refinements to be made to the calculated free-field exposure. For the purpose of this report, a neutron dose of one millirem is selected as the threshold and 1-mrem isodose contours (envelopes) are constructed. The envelopes, established as a function of weapon type, yield, height-of-burst, and atmospheric conditions determine the distance from a particular detonation for a free-field neutron dose of 1 mrem. The distance a participating unit or project was from the detonation, as obtained from the various source documents, is superimposed on the appropriate envelope; if the distance falls outside the 1-mrem isodose contour, the unit is excluded from further analysis, *i.e.*, it received a neutron dose of less than 1 mrem. However, if the distance falls within the 1-mrem envelope, the unit is identified in this report as having possibly received a neutron dose of at least 1 mrem (neglecting shielding). Details on the construction of the 1-mrem dose envelopes for continental and oceanic nuclear tests are found in Section 2. Those projects/units identified as having received a neutron dose of 1 mrem or greater are tabulated in Section 3. Of the several thousand units/projects screened, 160 are identified as having received a free-field neutron exposure exceeding 1 mrem. Of these, approximately 75 percent are aircrews with the remainder being ground-based units, either scientific projects or military observer/maneuver units.

SECTION 2

ISODOSE CONTOURS

2.1 CONTINENTAL ISODOSE CONTOURS .

Calculations are performed using Version 4 of the computer code ATR (Air Transport of Radiation) to characterize the neutron component of the radiation environment in the airspace surrounding the low yield nuclear detonations (1-80 KT) at NTS. ATR4 is a radiation environment prediction code that uses an extensive data base developed from detailed radiation transport calculations with computer codes ANISN and DOT. The use of these codes is described in Reference 1. Two specific cases are analyzed to bound the range of possible results.

- (1) Operation RANGER - Shot EASY. This shot is selected as representing the best-case scenario. The ATR neutron source spectrum used is that of a pure fission device, typical of the earlier weapons. The mean air density between the surface and the burst height (330 meters) is $1.18 \times 10^{-3} \text{ g/cm}^3$, a very high value for the Nevada shots. The high air density, and its corresponding neutron attenuation, results in a lower neutron dose at a given range.
- (2) Operation PLUMBBOB - Shot HOOD. This shot is selected as representing the worst-case scenario. The ATR neutron source spectrum used is that of a boosted fission device, typical of the later weapons. The mean air density between the surface and burst height (460 meters) is $0.992 \times 10^{-3} \text{ g/cm}^3$, the lowest of any low-altitude Nevada detonation. The low air density, coupled with the enhanced neutron output, results in a higher neutron dose at a given range.

In each case, an ATR calculation is made to determine neutron dose in rads (tissue) as a function of horizontal range along the surface, and as a function of slant range along radials from the burst point at angles of 30, 60, and 90 degrees to the horizontal. The mean air density between the surface and the burst point is used as a

reference point in the ATR atmospheric density gradient model to then determine the appropriate atmospheric density between the burst point and all other points of interest. The resulting neutron dose data are scaled linearly with yield to determine the neutron environment of similar detonations having different yields. Neutron rads are converted to rem using an effective quality factor of 13 for the energy spectrum of the neutrons emitted, as developed in Reference 2. Distances from the burst point along the surface and along the various radials to the 1-mrem dose equivalent level are determined and 1-mrem contours (envelopes) are constructed for each of six weapon yields. The contours shown in Figure 1 represent best and worst case conditions for neutron transport (Cases (1) and (2) above). The effect of decreasing air density with altitude is easily seen in the figures as the 1-mrem contours extend to greater distances above the burst point than along the surface radial.

2.2 OCEANIC ISODOSE CONTOURS .

For surface bursts conducted during the oceanic testing, calculations were performed with a multigroup one-dimensional discrete ordinates transport code (ANISN) to characterize the neutron component of the radiation environment in the airspace surrounding nuclear detonations at the Pacific Proving Grounds (PPG). The ANISN transport code allows for selective source spectra and transport media composition. For the present analysis, neutrons are transported from a point source in spherical geometry. Two sources are used:

- (1) A fission source, specifically that of the Nagasaki device (Fat Man), taken from the DNA Weapon Output Handbook. This source is similar to most of the early fission devices detonated at PPG.
- (2) A thermonuclear source, taken from D.E. Bartine, et al., "Production and Testing of the DNA Few-Group Coupled Neutron-Gamma Cross-Section Library," ORNL/TM-4840, March 1977. This source is representative of the medium-to-large yield thermonuclear devices detonated at the PPG.

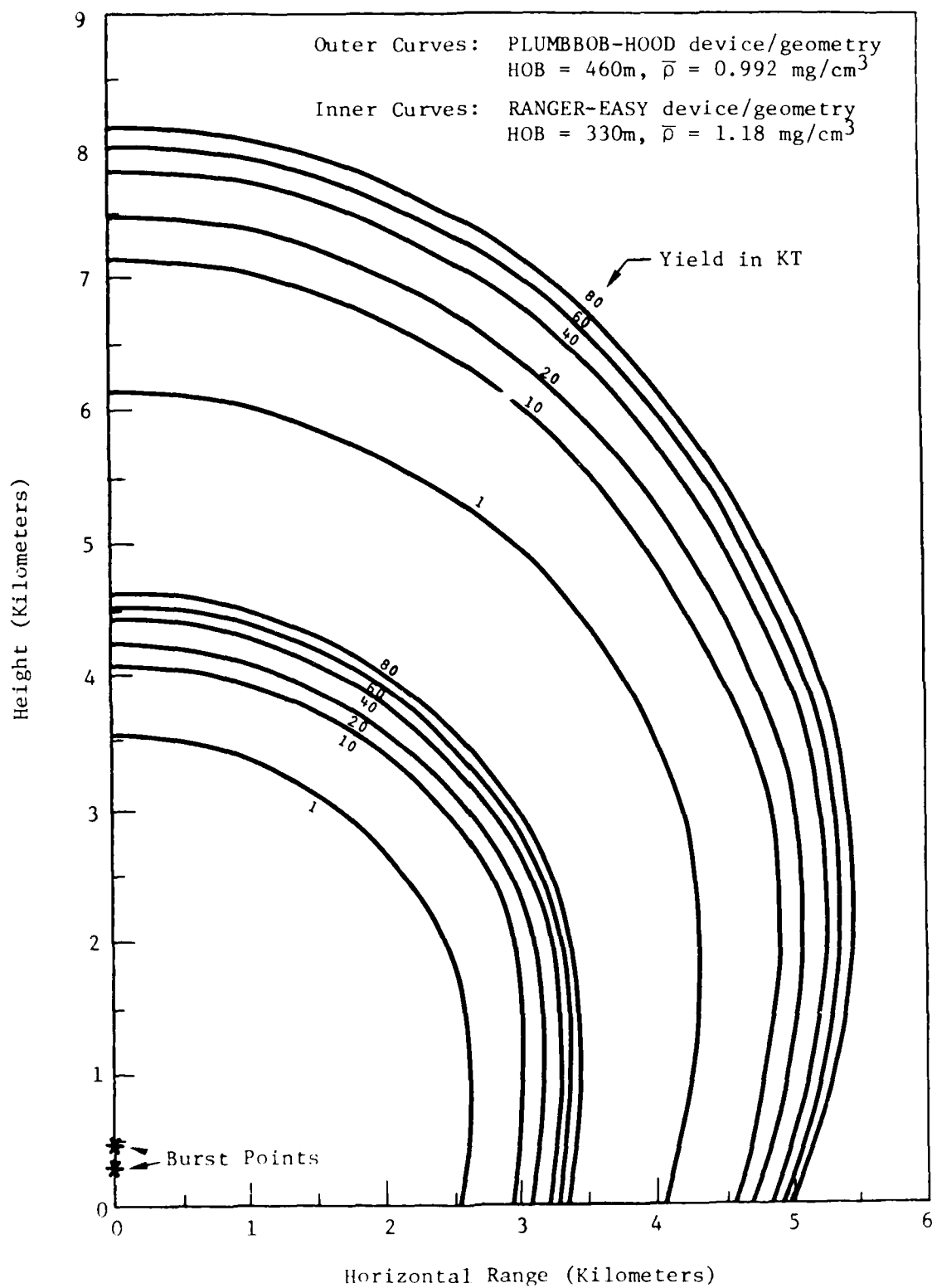


Figure 1. Neutron isodose (1 mrem) contours for continental detonations.

The atmosphere is assumed to be standard, with a density variation with altitude and an altitude-dependent moisture content derived from data given in DNA 4102T, "A Low Altitude Meteorological Data Base." The specific moisture content used in this analysis corresponds to that of Enewetak/Bikini during the winter (dry) period. For purposes of radiation transport calculations, the atmosphere is modeled as five homogeneous layers, with properties derived by averaging over each layer thickness. This atmosphere model is detailed as follows:

<u>Region</u>	<u>Altitude (km)</u>	<u>Avg Dry Air Density (g/cm³)</u>	<u>Avg Moisture Content (g H₂O/g dry air)</u>
I	0 - 2	1.11×10^{-3}	8.0×10^{-3}
II	2 - 4	9.10×10^{-4}	3.4×10^{-3}
III	4 - 6	7.37×10^{-4}	1.2×10^{-3}
IV	6 - 8	6.00×10^{-4}	6.0×10^{-4}
V	8 - 10	4.66×10^{-4}	4.0×10^{-4}

ANISN calculations are made to determine neutron dose in rads (tissue) per source neutron as a function of range along radials from the burst point. Calculations are performed at angles of 30°, 60°, and 90° up from the horizontal. Calculations were not made along the surface since the one-dimensional ANISN results do not include the perturbing effects of the air-sea interface. Much more extensive 2-D calculations are required to accurately define the neutron dose as a function of range in this region. The properties of the transport medium are derived from the 5-layer model, with the thickness of each layer scaled as the reciprocal of the sine of the angle the radial makes with the horizontal; for example, at 30° from the horizontal, layer thickness = 2 km/sin 30°.

Normalized ANISN output, in rads (tissue) per source neutron, are converted to rem by assuming a neutron output of 2.0×10^{23} neutrons/KT (a representative value for these weapon types) and an effective neutron quality factor of 13. These values are then used to construct 1-mrem contours for various weapon yields for each of the two weapon types. The results are shown in Figure 2. Although not drawn to sea

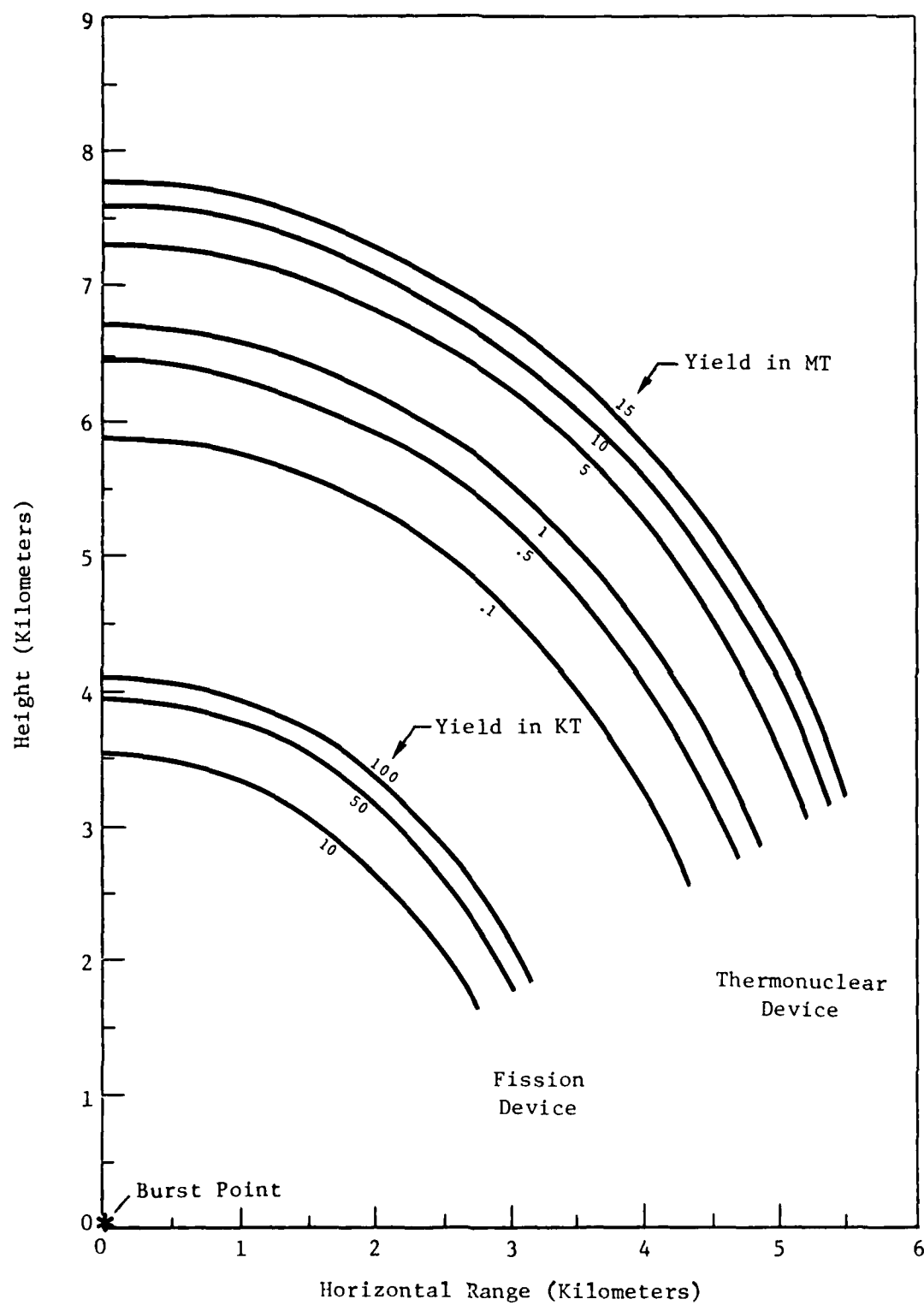


Figure 2. Neutron isodose (1 mrem) contours for oceanic detonations - surface bursts.

level, the isodose contours would tend to bend inward toward surface zero if 2-D transport calculations were performed to define the neutron environment in this region.

For the airbursts conducted during the oceanic testing, calculations were performed using ATR4 to characterize the neutron environment. Since ATR4 does not consider the effect of moisture in the air on neutron transport, the 1-mrem isodose envelopes thus constructed tend to be high-sided in estimating the slant range to 1 mrem, i.e., calculated slant ranges using ATR4 are greater than the actual slant ranges to 1 mrem. Four combinations of weapon yield and height-of-burst were used to construct the isodose curves in Figure 3:

- (1) A 100KT (0.8 fission fraction) source at a height-of-burst of 1.0 km
- (2) A 500KT (0.8 fission fraction) source at a height-of-burst of 1.5 km
- (3) A 1MT thermonuclear source at a height-of-burst of 2.7 km
- (4) A 10MT thermonuclear source at a height-of-burst of 3.5 km

These particular combinations of yield and height-of-burst typify the many airdropped weapons detonated during the oceanic testing, especially during Operation DOMINIC I. When the contours in Figure 3 are compared to the 1-mrem contours in Figure 2 for surface bursts, the effect of decreased air density (and atmospheric moisture) at the higher heights-of-burst on neutron transport is clearly evident by the much greater distances to 1-mrem.

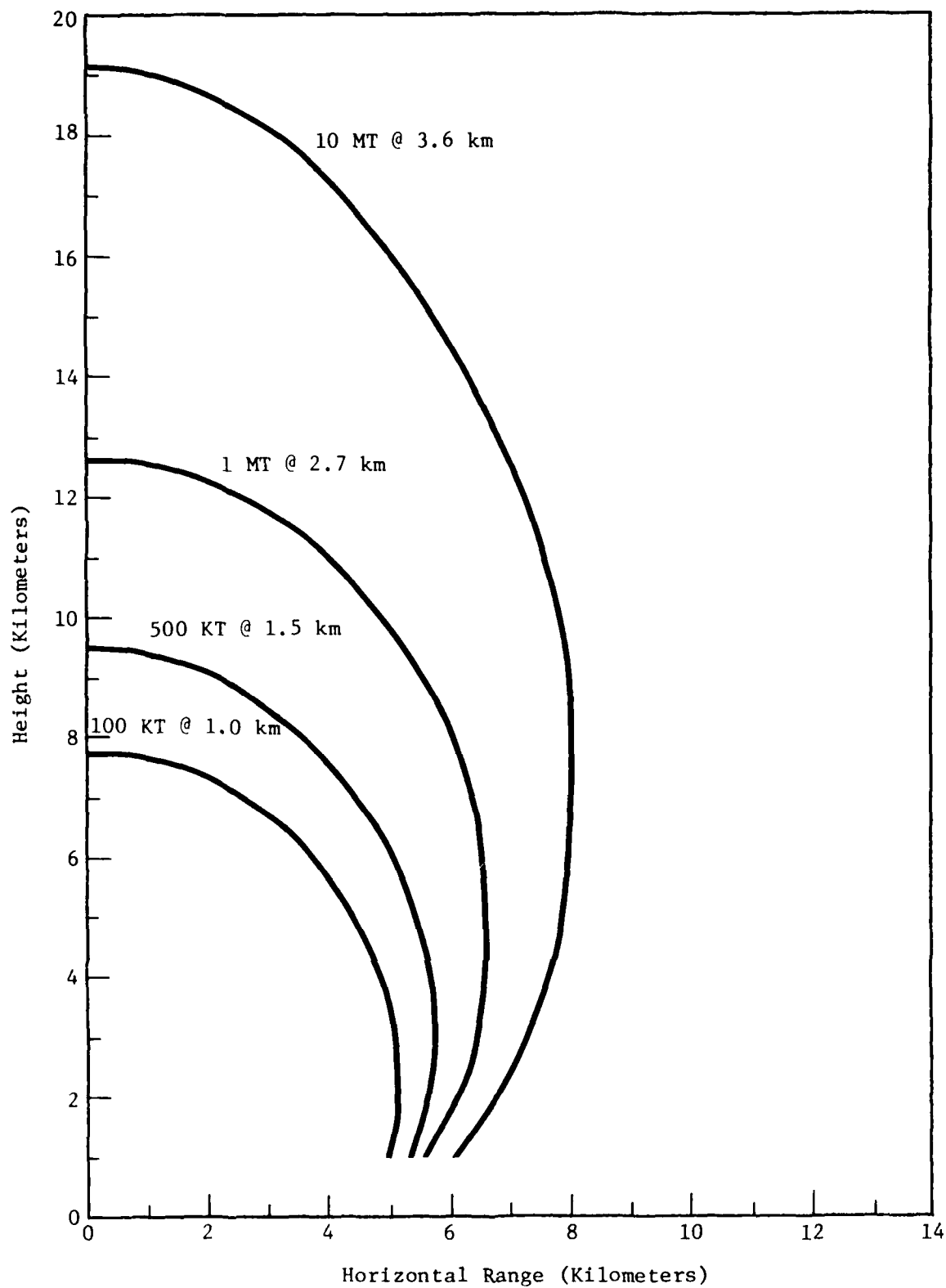


Figure 3. Neutron isodose (1 mrem) contours for oceanic detonations - air bursts.

SECTION 3 DOD PERSONNEL RECEIVING NEUTRON DOSES

3.1 CONTINENTAL OPERATIONS.

DoD personnel participating at Nevada tests witnessed shots from several locations. Most were at News Nob near the Control Point (approximately 10 kilometers from the closest shot) and far enough from any shot to be out of range of significant initial effects, including neutron exposure. However, many troops who participated in the Desert Rock exercises observed a shot from a closer distance, generally from 2.5 to 5 kilometers from the burst, depending on the yield. These troops were normally in trenches, but some were in armored vehicles or even in the open. In some cases, volunteer observers (whose identities are all known) were positioned in trenches slightly more than 1.8 kilometers from the burst.

Aircraft were normally located at sufficient distances from a detonation to avoid any detrimental blast effect. There were cases where delivery (and simulated delivery) aircraft were close enough at the time of burst for the crew to have received a neutron dose. Other aircraft, such as those in aircraft structures tests, were also close enough to receive a neutron dose on several occasions.

Neutron doses are calculated for most DoD observers and maneuver troops who participated at the continental detonations (e.g., Reference 1). The results of these calculations, which consider the shielding provided by trenches and armored vehicles, are tabulated in this report for those participants who received a neutron dose of 1 mrem or more. The isodose contours shown in Figure 1 are used to identify other projects, units, and aircrews whose activities resulted in possible neutron exposures. These units, and the specific operations/shots at which they participated, are identified in this report for subsequent determination of their neutron dose.

Some DoD personnel received neutron doses of 1 mrem or greater in seven of the eight atmospheric test operations conducted in Nevada. At TRINITY (in New Mexico) and Operation RANGER, none of the units/projects involved received neutron doses

exceeding 1 mrem. Those in the remaining seven operations that received neutron doses of 1 mrem or more are tabulated in Tables 1 through 7. If a unit/project is not listed, this indicates a neutron exposure of less than 1 mrem. If a neutron dose has previously been reconstructed for a particular unit, the calculated dose is given. An "X" in the table indicates a possible neutron dose of 1 mrem or greater that should be verified through subsequent dose reconstructions.

Table 1. DoD personnel receiving a neutron dose at Operation BUSTER-JANGLE.

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot					
	<u>BAKER</u>	<u>CHARLIE</u>	<u>DOG</u>	<u>EASY</u>	<u>SUGAR</u>	<u>UNCLE</u>
Weapon Delivery Aircrew	X	X	X	X		
Project 4.1 Aircrew					0.026	
Project 6.5 Aircrew			X	X		
Project 8.4 Photographers (On Project 6.5 Aircraft)			X	X		

Table 2. DoD personnel receiving a neutron dose at Operation TUMBLER-SNAPPER.

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot					
	<u>BAKER</u>	<u>CHARLIE</u>	<u>DOG</u>	<u>EASY</u>	<u>FOX</u>	<u>HOW</u>
Weapon Delivery Aircrew	X	X	X			
Project 1.1 Aircrew				X		X
Project 6.4 Aircrew	X	X	X		X	

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

Table 3. DoD personnel receiving a neutron dose at Operation UPSHOT-KNOTHOLE.

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot								
	<u>ANNIE</u>	<u>NANCY</u>	<u>DIXIE</u>	<u>BADGER</u>	<u>SIMON</u>	<u>ENCORE</u>	<u>HARRY</u>	<u>GRABLE</u>	<u>CLIMAX</u>
Observers	0.018				.003				
Volunteer Observers		0.63		2.4	28				
Battalion Combat Teams A&B	0.018				.003				
Weapon Delivery Aircrew			X			X			X
Project 1.3 Aircrew and Ground Personnel			X			X			
			X						
Project 4.1 Aircrew			X			X			
Project 5.1 Aircrew	X	X		X	X	X	X		
Project 5.2 Aircrew			X			X			
Project 5.3 Aircrew						X			
Project 6.2 Aircrew			X			X			
Project 6.3 Aircrew			X	X	X	X	X		
Project 6.11 Aircrew			X			X			

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

Table 4. DoD personnel receiving a neutron dose at Operation TEAPOT.

PARTICIPANTS	Neutron Dose (rem) at Shot										
	WASP	MOTH	TESLA	TURK	HORNET	BEE	APL-1	WASP PRIME	HA	MET	APL-2
Observers		0.16	1.4			0.01	0.029				.063
Maneuver Troops						0.01					
Volunteer Observers											4.5
Task Force RAZOR											
Co. "A", 723rd Tank Bn.											0.39
Co. "C", 723rd Tank Bn.											0.14
Tank Command Gp.											0.27
Co. "B", 723rd Tank Bn.											0.013
Armored Inf. Plt. (Rt)											0.031
Armored Inf. Plt. (Left)											0.004
Armored Inf. Plt. (Ctr)											0.010
Staff Element											0.021

Table 4. DoD personnel receiving a neutron dose at Operation TEAPOT (Concluded).

PARTICIPANTS	Neutron Dose (rem) at Shot										
	WASP	MOTH	TESLA	TURK	HORNET	BEE	APL-1	WASP PRIME	HA	MET	APL-2
Weapon Delivery Aircrew	X							X	X		
Project 1.2 Aircrew									X		
Project 5.1 Aircrew						X				X	
Project 5.2 Aircrews				0.024*	X	1.4*	0.007			X	
Project 6.4 Aircrew									X		
Project 8.1 Aircrews						0.15*	0.002			X	0.039*
Project 8.4a Personnel (On Delivery Aircraft)									X		
Project 9.1 Aircrew									X		
Project 40.3 Aircrew		X	X								
Project 40.4 Aircrew				0.002							
Project 40.12 Aircrew					X						

* Applies to closest aircraft. Other aircraft received less than 0.001 rem.

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

Table 5. DoD personnel receiving a neutron dose at Operation PLUMBBOB.

PARTICIPANTS	Neutron Dose (rem) at Shot											
	<u>BLTZMN</u>	<u>WLSN</u>	<u>PRSCLA</u>	<u>HOOD</u>	<u>DIABLO</u>	<u>JOHN</u>	<u>KEPLER</u>	<u>STOKES</u>	<u>SHASTA</u>	<u>DPLR</u>	<u>FRNKLN</u> <u>PRIME</u>	<u>SMOKY</u> <u>GALILEO</u>
Observers			0.002		0.001*		0.012*			0.133		
Volunteer Observers						0.007						
Task Force BIG BANG												0.010
Task Force WARRIOR										.227		
Weapon Delivery and Alternate Aircrew						16.5 1.0						
Project 5.1 Aircrew	X	X	0.010		X			X				
Project 5.3 Aircrews	X			2.9 4.9**	X				X			X
Project 5.4 Aircrew	X		1.76	5.32	X				X	X		X
Project 5.5 Aircrew	X			0.081		16.5		X		X	X	
Project 6.5							X					
Project 50.8							X					

* Estimate based on assumed scenarios for similar yields and heights-of-burst

** Applies to closest aircraft

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

Table 6. DoD personnel receiving a neutron dose at Operation HARDTACK II.

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot			
	<u>QUAY</u>	<u>HMLTN</u>	<u>R-ARRIBA</u>	<u>HMBLT</u>
Project 4.3		X		
Project 8.8	X	X	X	X
1352nd Motion Picture Squadron		X		

Table 7. DoD personnel receiving a neutron dose at Operation DOMINIC II.

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot			
	<u>LTL FLR2</u>	<u>JNIE BOY</u>	<u>SMALL BOY</u>	<u>LTL FLR1</u>
IVY FLATS Maneuver Troops				X
IVY FLATS Military Observers				X
Project 7.12			X	
Project 7.13 Aircrew			X	
Project 7.15 Aircrew			X	
Project 7.16 Aircrew	X		X	
Project 8.1				0.001
Project 9.2	X	X	X	0.50

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

3.2 OCEANIC OPERATIONS.

Most of the nuclear test operations conducted in the Pacific were held at either Bikini or Enewetak Atolls. DoD participants (except aircrews) at Operations CROSSROADS (1946), SANDSTONE (1948), GREENHOUSE (1951), IVY (1952), CASTLE (1954), REDWING (1956), and HARDTACK I (1958), observed the detonations in the open either from ships or from residence islands on the atolls, well removed (at least 12 kilometers) from any of the shots. It is evident from Figure 2 that no one observing the tests from these locations received a neutron dose of 1 mrem or more. Operation WIGWAM (1955), an underwater detonation approximately 800 kilometers southwest of San Diego, and Operation ARGUS (1958), a series of three high-altitude tests conducted in the South Atlantic, did not result in any participant receiving a neutron dose. During Operations HARDTACK I and DOMINIC I (1962), rocket launched weapons were detonated directly over Johnston Island, but at altitudes (> 18 kilometers) precluding any neutron exposure to island-based personnel and participating shipboard units. The many airdropped weapons at DOMINIC I were detonated either 16-32 kilometers south of Christmas Island or 400-600 kilometers from Johnston Island; the closest ships to any of the airdrops were at least 16 kilometers from surface zero (at anchor off Christmas Island), again precluding the possibility of island-based or shipboard personnel receiving a neutron exposure. Another test during Operation DOMINIC I, a low-yield underwater burst, was conducted 680 kilometers southwest of San Diego, California. There was no neutron dose for any participant.

As in the continental test operations, aircraft were normally positioned at sufficient distances from the detonation to avoid damaging blast effects. There were, however, instances during the oceanic testing where test aircraft were within range of a neutron dose. The isodose contours in Figure 2 are used to identify those aircrews whose activities resulted in possible neutron exposures from the many surface detonations conducted during the oceanic testing. The isodose contours in Figure 3 are used primarily for the B-52 crews who delivered the weapons that were dropped during Operation DOMINIC I; they are also used in conjunction with the airdrops at Operations CROSSROADS (ABLE), IVY (KING), and REDWING (CHEROKEE and

OSAGE). Of the twenty-nine airdrops conducted during Operation DOMINIC I, the slant range between the drop aircraft (the closest aircraft) and the detonation are known for ten of the tests. While participating in these ten tests, the drop aircraft remained well outside (at least 4 kilometers) of the 1-mrem contours determined for each of the yields and heights-of-burst. It is assumed that similar operational procedures were followed for the remaining nineteen detonations for which the slant ranges are not known, and that the aircrews participating at these tests were not exposed to neutron radiation.

Only two of the ten operations conducted in oceanic areas resulted in participants receiving a neutron dose of 1 mrem or greater. The project personnel identified as having received neutron exposures at Operations REDWING and HARDTACK I are tabulated in Table 8 and Table 9, respectively.

Table 8. DoD personnel receiving a neutron dose at Operation REDWING.

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot							
	<u>LACROSSE</u>	<u>ERIE</u>	<u>FLTHEAD</u>	<u>KICKAPOO</u>	<u>INCA</u>	<u>DAKOTA</u>	<u>MOHAWK</u>	<u>HURON</u>
Project 5.3 Aircrew						X		X
Project 5.4 Aircrew		X			X			
Project 5.5 Aircrew						X	X	
Project 5.6 Aircrew	X			X	X			
Project 5.8 Aircrew			X					X

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

Table 9. DoD personnel receiving a neutron dose at Operation HARDTACK I

<u>PARTICIPANTS</u>	Neutron Dose (rem) at Shot					
	<u>CACTUS</u>	<u>BTRNUT</u>	<u>KOA</u>	<u>MAGNOLIA</u>	<u>TOBACCO</u>	<u>WALNUT</u>
Project 5.2 Aircrew	0.105*	X	X	0.030*	0.020**	0.015*
Project 5.3 Aircrew	0.135*					X

* Doses based on sulfur packet measurements

** Aircraft position falls outside 1 mrem contour

"X" indicates a possible neutron dose of 1 mrem or greater which will be verified through subsequent dose calculations.

SECTION 4

CONCLUSIONS

Military units and scientific projects that participated in the US atmospheric nuclear testing program were screened to determine if exposure to neutron radiation was a significant contributor to an individual's total dose. Of all the projects/units screened, 160 are identified as receiving a probable neutron dose of 1 mrem or more. Of these, approximately 75 percent are aircrews with the remainder being ground-based units (either scientific projects or military observer/maneuver units). Neutron dose calculations have previously been performed (e.g., References 3 and 4) for all military observer and maneuver troops except those identified in this report as being participants in the IVY FLATS troop exercises at Operation DOMINIC II. Neutron dose calculations are to be performed for personnel assigned to eight scientific projects fielded during Operations PLUMBBOB (2 projects), HARDTACK II (3 projects), and DOMINIC II (3 projects). Likewise, neutron doses are to be quantified for the aircrews identified in this report as having a potential neutron dose of 1 mrem or more. The projects/units identified in this report are those for which neutron doses have been previously calculated or that received a free-field neutron dose of at least 1 mrem. Subsequent detailed dose calculations, which will include the effect of shielding, will likely decrease the number of projects/units that actually received a neutron exposure exceeding 1 mrem.

SECTION 5

LIST OF REFERENCES

1. "Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE," DNA 5742F, Defense Nuclear Agency, 28 April 1981. AD/A 116 921.*
2. "Analysis of Radiation Exposure for Task Force WARRIOR, Shot SMOKY, Exercise Desert Rock VII-VIII, Operation PLUMBBOB," DNA 4747F, Defense Nuclear Agency, 31 May 1979. AD/A 070 239.*
3. "Analysis of Radiation Exposure for Task Force BIG BANG, Shot GALILEO, Exercise Desert Rock VII-VIII, Operation PLUMBBOB," DNA 4772F, Defense Nuclear Agency, 9 April 1980. AD/A 085 801.*
4. "Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock VI, Operation TEAPOT," DNA 5354F, Defense Nuclear Agency, 15 July 1980. AD/A 121 701.*

***Available from:** National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161 Phone: (703) 487-4650

Also available from: Coordination and Information Center
P.O. Box 14400
Las Vegas, Nevada 89114-4400 Phone: (702) 295-0731

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

ARMED FORCES RADIOBIOLOGY RSCH INST

ATTN: DEPUTY DIRECTOR
ATTN: DIRECTOR
ATTN: SCIENTIFIC DIRECTOR
ATTN: TECHNICAL LIBRARY

ASST SECY OF DEFENSE PUBLIC AFFAIRS
ATTN: ASD(PA)

ASSISTANT SECRETARY OF DEFENSE
ATTN: ASD(HA)

DEFENSE INTELLIGENCE AGENCY
ATTN: RTS-2B

DEFENSE NUCLEAR AGENCY

ATTN: GC
ATTN: PAO
10 CYS ATTN: STBE
54 CYS ATTN: STTI-CA

DEFENSE TECHNICAL INFORMATION CENTER
12 CYS ATTN: DD

DEP UNDER SEC OF DEF FOR RSCH & ENGRG
ATTN: DUSDRE RSCH & ADV TECH

FIELD COMMAND DEFENSE NUCLEAR AGENCY

ATTN: FCL
2 CYS ATTN: FCLS
ATTN: FCTT W SUMMA
ATTN: FCTXE
ATTN: FCTXE

FIELD COMMAND DNA DET 2
LAWRENCE LIVERMORE NATIONAL LAB
ATTN: FC-1

DEPARTMENT OF THE ARMY

HARRY DIAMOND LABORATORIES
ATTN: SLCIS-IM-TL 81100 TECH LIB

HQ DEPARTMENT OF THE ARMY
5 CYS ATTN: DAAG-ESG-N, NTPR

U S ARMY BALLISTIC RESEARCH LAB
ATTN: DRDAR-BLV-R J MALONEY

U S ARMY CTR OF MILITARY HISTORY
ATTN: LIBRARY

U S ARMY MEDICAL RSCH & DEV CMD
ATTN: SGRD-SD

U S ARMY NUCLEAR & CHEMICAL AGENCY
ATTN: MONA-ZB C DAVIDSON

WALTER REED ARMY MEDICAL CENTER
ATTN: LIBRARY

DEPARTMENT OF THE NAVY

MARINE CORPS HISTORY & MUSEUMS
ATTN: HISTORICAL DIVISION

NATIONAL NAVAL MEDICAL CENTER
ATTN: DEPT OF RADIOLOGY
ATTN: MEDICAL LIBRARY

NAVAL HISTORICAL CENTER
ATTN: DD ALLARD

NAVAL MEDICAL COMMAND
ATTN: MEDCOM-21
ATTN: NM&S-00
ATTN: NM&S-09

NAVAL OCEAN SYSTEMS CENTER
ATTN: TECH LIB CODE 9642

NAVAL SEA SYSTEMS COMMAND
ATTN: SEA-08 M MILES

NAVAL WEAPONS EVALUATION FACILITY
ATTN: CLASSIFIED LIBRARY

OFC OF THE DEPUTY CHIEF OF NAVAL OPS
5 CYS ATTN: NOP 0455

DEPARTMENT OF THE AIR FORCE

AEROSPACE MEDICAL DIVISION, AFSC
ATTN: LIBRARY SCL-4

AIR FORCE HISTORICAL RSCH CTR
ATTN: LIBRARY

AIR FORCE INSTITUTE OF TECHNOLOGY/EN
ATTN: LIBRARY/AFIT/LDEE

AIR FORCE NUCLEAR TEST REVIEW
4 CYS ATTN: SGPT COL GIBBONS

AIR FORCE WEAPONS LABORATORY, AFSC
ATTN: NT
ATTN: SUL

AIR UNIVERSITY LIBRARY
ATTN: AUL-LSE

DEPARTMENT OF THE AIR FORCE (CONTINUED)

U S AIR FORCE OCCUPATIONAL & ENV HEALTH LAB
4 CYS ATTN: AFNTPR
ATTN: R2

DEPARTMENT OF ENERGY

DEPARTMENT OF ENERGY
ATTN: OMA DP-22

DEPARTMENT OF ENERGY
ATTN: B CHURCH HPD

DEPARTMENT OF ENERGY
ATTN: J THIESEN
ATTN: TECH INFO CTR

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE NATIONAL LAB
ATTN: L ANSPAUGH
ATTN: L-53 TECH INFO DEPT LIB
ATTN: Y NG

LOS ALAMOS NATIONAL LABORATORY
ATTN: F601 T DOWLER
ATTN: ITO D STILLMAN
ATTN: P WHALEN

OAK RIDGE NATIONAL LABORATORY
ATTN: C RICHMOND
ATTN: G KERR

OAK RIDGE NATIONAL LABORATORY
ATTN: T JONES

REYNOLDS ELECTRICAL AND ENGR CO, INC
ATTN: CIC
ATTN: LST
ATTN: W BRADY

OTHER GOVERNMENT

CANCER CENTER, NIH
ATTN: A KNUDSON

CENTRAL INTELLIGENCE AGENCY
ATTN: OFFICE OF MED SVCS

CONSUMER PRODUCT SAFETY COMMISSION
ATTN: M BLOOM
ATTN: P PRUESS

DEPARTMENT OF COMMERCE
ATTN: C KUYATT
ATTN: J HUBBELL
ATTN: M EHRLICH

DEPT OF HEALTH & HUMAN SERVICES
ATTN: OFC OF REG REVIEW

DEPARTMENT OF HEALTH & HUMAN SVCS
ATTN: R MURPHY

DEPARTMENT OF LABOR
ATTN: S WEINER

DEPARTMENT OF TRANSPORTATION
ATTN: H L REIGHARD

DEPT OF HEALTH & HUMAN SERVICES
ATTN: C SILVERMAN
ATTN: G JOHNSON
ATTN: J VILLFORTH

ENVIRONMENTAL PROTECTION AGENCY
ATTN: P MAGNO
ATTN: T THORSLUND

ENVIRONMENTAL PROTECTION AGENCY
ATTN: N NELSON

FEDERAL EMERGENCY MANAGEMENT AGENCY
ATTN: C SIEBENTRITT
ATTN: H TOVEY
ATTN: OFC OF RSCH/NP H TOVEY

LIBRARY OF CONGRESS
ATTN: SCI & TECH DIV

NASA HEADQUARTERS
ATTN: P RAMBAUT

NATIONAL CANCER INSTITUTE, NIH
ATTN: B WACHOLZ
ATTN: G BEEBE
ATTN: V ZEVE

NATIONAL CANCER INSTITUTE, NIH
ATTN: C LAND
ATTN: J FRAUMENI
ATTN: W BLOT

NATIONAL CANCER INSTITUTE, NIH
ATTN: J GART

NATIONAL CANCER INSTITUTE, NIH
ATTN: A RABSON
ATTN: D PISTENMAA
ATTN: J WYNGAARDEN

NATIONAL INSTITUTE FOR OCCUPATIONAL
ATTN: W MURRAY

NATIONAL INSTITUTES OF HEALTH
ATTN: LIBRARY ACQ UNIT

OTHER GOVERNMENT (CONTINUED)

NATIONAL LIBRARY OF MEDICINE, NIH
ATTN: LIBRARY

NATIONAL SCIENCE FOUNDATION
ATTN: P HARRLMAN

OFFICE ON SMOKING & HEALTH
ATTN: J PINNEY

SUBCOMMITTEE OF NUCLEAR REGULATORY
ATTN: J CURTISS

U S HOUSE OF REPRESENTATIVES
ATTN: SUBCOM ON MIL PER & COMP

U S HOUSE OF REPRESENTATIVES
ATTN: SUBCOM ON HEALTH & ENVIR

U S HOUSE OF REPRESENTATIVES
2 CYS ATTN: MAJORITY COUNSEL

U S NUCLEAR REGULATORY COMMISSION
ATTN: R WHIPP FOR F ARSENAULT
ATTN: R WHIPP FOR R MINOGUE

U S PUBLIC HEALTH SERVICE
ATTN: LIBRARY

U S SENATE
ATTN: J MCGOVERN

U S SENATE
3 CYS ATTN: MAJORITY COUNSEL

U S SENATE
ATTN: S ULM SENATE COURT

VETERANS ADMIN MEDICAL CENTER
ATTN: K LEE

VETERANS ADMIN MEDICAL CENTER
ATTN: D MCGREGOR

VETERANS ADMIN MEDICAL CENTER
ATTN: C TESSMER

VETERANS ADMIN WADSWORTH HOSPITAL CTR
ATTN: T MAKINODAN

VETERANS ADMINISTRATION
ATTN: A GRAHAM RADIOLOGY
ATTN: COMPENSATION
ATTN: D BOSCH (BVA)
2 CYS ATTN: D STARBUCK
ATTN: L HOBSON

VETERANS ADMINISTRATION HOSPITAL
ATTN: R YALOW

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

OTHER GOVERNMENT (CONTINUED)

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO
ATTN: DIRECTOR

WHITE HOUSE (THE)
ATTN: OFC OF POL DEV (DP)

DEPARTMENT OF DEFENSE CONTRACTORS

ADVANCED RESEARCH & APPLICATIONS CORP
ATTN: R ARMISTEAD

BDM CORP
ATTN: J BRADDOCK

JAYCOR
ATTN: A NELSON INFO SYS DIV

KAMAN TEMPO
ATTN: DASIAC

LOUISIANA UNIV SCH OF MED, SHREVEPORT
ATTN: LIBRARY

DEPT OF DEFENSE CONTRACTORS (CONTINUED)

NATIONAL ACADEMY OF SCIENCES

ATTN: C ROBINETTE
ATTN: R COHEN
ATTN: S JABLON

NEBRASKA, UNIVERSITY OF
ATTN: LIBRARY

NORTHROP CORP
ATTN: Z SHANFIELD

OHIO STATE UNIVERSITY
ATTN: LIBRARY

PACIFIC-SIERRA RESEARCH CORP
ATTN: H BRODE, CHAIRMAN SAGE

R & D ASSOCIATES
ATTN: C K B LEE

R & D ASSOCIATES
ATTN: A DEVERILL

RADIATION RESEARCH ASSOCIATES, INC
ATTN: N SCHAEFFER

RAND CORP
ATTN: P DAVIS
ATTN: TECH LIBRARY

RAND CORP
ATTN: B BENNETT

SCIENCE APPLICATIONS INTL CORP
2 CYS ATTN: C THOMAS
2 CYS ATTN: J GOETZ
ATTN: J MCGAHAN
ATTN: M BARRETT
2 CYS ATTN: R WEITZ
2 CYS ATTN: W KLEMM

SCIENTIFIC INFORMATION SERVICES, INC
ATTN: LIBRARY

FOREIGN

CANADIAN EMBASSY
ATTN: LIBRARY

EDF—RETN 1
ATTN: LIBRARY

INDIAN COUNCIL OF MEDICAL RSCH
ATTN: A TASKAR

JAPAN-HAWAII CANCER STUDY
ATTN: G GLOBER

MAURICE DELPLA
ATTN: M DELPLA

MCGILL UNIVERSITY
ATTN: R OSEASOHN

PRESIDENTE UMBERTO COLOMBO
ATTN: LIBRARY

PUERTO RICO SCH OF MEDICINE, UNIV OF
ATTN: LIBRARY

UNITED KINGDOM SCIENTIFIC MISSION
ATTN: MIL LIASION FOR DR RIDLEY

DIRECTORY OF OTHER

AKRON PUBLIC LIBRARY
ATTN: GOVT PUB LIBRARIAN

ALABAMA, UNIVERSITY OF
ATTN: DIR OF LIBS REGIONAL

ALASKA, UNIVERSITY OF
ATTN: DIR OF LIBRARIES

ALLEN COUNTY PUBLIC LIBRARY
ATTN: LIBRARIAN

ANAHEIM PUBLIC LIBRARY
ATTN: LIBRARIAN

ARIZONA UNIVERSITY
ATTN: LIBRARIAN

ARKANSAS COLLEGE LIBRARY
ATTN: LIBRARY

ARKANSAS LIBRARY COMM
ATTN: LIBRARY

ARKANSAS, UNIVERSITY OF
ATTN: GOVT DOCS DIV

BEMIOJI STATE COLLEGE
ATTN: LIBRARY

BRIGHAM YOUNG UNIVERSITY
ATTN: DOCS COLLECTION

BROOKHAVEN NATIONAL LABORATORY
ATTN: A B BRILL MED DEPT
ATTN: E CRONKITE MED DEPT
ATTN: M BENDER MED DEPT
ATTN: TECHNICAL LIBRARY
ATTN: V BOND

BURLINGTON LIBRARY
ATTN: LIBRARIAN

DIRECTORY OF OTHER (CONTINUED)

CALIFORNIA INSTITUTE OF TECHNOLOGY
ATTN: E LEWIS
ATTN: R CHRISTY

CALIFORNIA STATE LIBRARY (REGIONAL)
ATTN: LIBRARIAN

CALIFORNIA STATE UNIVERSITY
ATTN: LIBRARIAN

CALIFORNIA UNIVERSITY
ATTN: GOVT DOCS DEPT

CALVIN T RYAN LIBRARY
ATTN: GOVT DOCS DEPT

CENTRAL FLORIDA UNIV OF
ATTN: LIBRARY DOCS DEPT

CENTRAL WASHINGTON UNIVERSITY
ATTN: LIBRARY DOCS SECTION

CHARLESTON COUNTY LIBRARY
ATTN: LIBRARIAN

CHARLOTTE & MECHLENBURG COUNTY PUB LIB
ATTN: E CORRELL

CHATTANOOGA HAMILTON CO
ATTN: LIBRARIAN

CHICAGO PUBLIC LIBRARY
ATTN: GOVS PUBS DEPT

CHICAGO, UNIVERSITY OF
ATTN: P MEIER

COLORADO STATE UNIV LIBS
ATTN: LIBRARIAN

COLORADO, UNIVERSITY OF
ATTN: LIBRARY

COLUMBIA UNIVERSITY
ATTN: A BLOOM
ATTN: LIBRARY

COLUMBIA UNIVERSITY
ATTN: DIV OF BIOSTATS

COORDINATION & INFORMATION CTR
ATTN: C/O REECD

CORNELL UNIVERSITY
ATTN: W FEDERER

DALLAS PUBLIC LIBRARY
ATTN: LIBRARIAN

DAYTON & MONTGOMERY CITY PUB LIB
ATTN: LIBRARIAN

DECATUR PUBLIC LIBRARY
ATTN: LIBRARIAN

DELTA STATE UNIVERSITY
ATTN: LIBRARIAN

DETROIT PUBLIC LIBRARY
ATTN: LIBRARIAN

DICKINSON STATE COLLEGE
ATTN: LIBRARIAN

DREW UNIVERSITY
ATTN: LIBRARY

DULUTH PUBLIC LIBRARY
ATTN: DOCUMENTS SECTION

EAST CAROLINA UNIVERSITY
ATTN: LIBRARY DOCS DEPT

EASTERN BRANCH
ATTN: LIBRARIAN

EL PASO PUBLIC LIBRARY
ATTN: DOCS & GENEOLGY DEPT

ENOCH PRATT FREE LIBRARY
ATTN: DOCUMENTS OFFICE

EVANSVILLE & VANDERBURGH COUNTY PUB LIB
ATTN: LIBRARIAN

FLORIDA STATE UNIVERSITY
ATTN: DOCUMENTS DEPT

FOND DU LAC PUBLIC LIB
ATTN: LIBRARIAN

FORT HAYS STATE UNIVERSITY
ATTN: LIBRARIAN

FORT WORTH PUBLIC LIBRARY
ATTN: LIBRARIAN

FRESNO COUNTY FREE LIBRARY
ATTN: LIBRARIAN

GADSEN PUBLIC LIBRARY
ATTN: LIBRARIAN

GEORGIA, MEDICAL COLLEGE OF
ATTN: L STODDARD

GRAND RAPIDS PUBLIC LIBRARY
ATTN: DIR OF LIBRARIES

DIRECTORY OF OTHER (CONTINUED)

GUAM RFK MEMORIAL UNIVERSITY LIB
ATTN: FED DEPOSITORY COLLECTION

HARVARD SCHOOL OF PUBLIC HEALTH
ATTN: J BAILOR
ATTN: LIBRARY
ATTN: R REED

HARVARD SCHOOL OF PUBLIC HEALTH
ATTN: B MACMAHON

HARVARD UNIVERSITY
ATTN: W COCHRAN

HAWAII, UNIVERSITY OF
ATTN: Y MATSUMOTO

HOPKINSVILLE COMM COLL
ATTN: LIBRARIAN

IDAHO STATE UNIVERSITY LIBRARY
ATTN: DOCS DEPARTMENT

IDAHO, UNIVERSITY OF
ATTN: DIR OF LIBS REGIONAL

ILLINOIS STATE LIBRARY (REGIONAL)
ATTN: GOVT DOCUMENTS BR

INDIANA STATE LIBRARY (REGIONAL)
ATTN: SERIAL SECTION

INDIANA UNIVERSITY
ATTN: F PUTNAM

IOWA STATE UNIVERSITY
ATTN: T BANCROFT

JOHNS HOPKINS UNIVERSITY
ATTN: A KIMBALL
ATTN: R SELTSE

KANSAS CITY PUBLIC LIBRARY
ATTN: DOCUMENTS DIV

KANSAS STATE LIBRARY
ATTN: LIBRARIAN

KANSAS STATE UNIV LIBRARY
ATTN: DOCUMENTS DEPT

KANSAS UNIV OF AGRI & APPLIED SCIENCE
ATTN: H FRYER

KENTUCKY DEPT OF LIBRARY & ARCHIVES
ATTN: DOCUMENTS SECTION

KENTUCKY, UNIVERSITY OF
ATTN: DIR OF LIBS REGIONAL

KINGSTON HOSPITAL
ATTN: K JOHNSON

LOS ANGELES PUBLIC LIBRARY
ATTN: SERIALS DIV U S DOCS

LOUISIANA STATE UNIVERSITY
ATTN: DIR OF LIBS

MAINE UNIVERSITY, OF
ATTN: LIBRARIAN

MANKATO STATE COLLEGE
ATTN: GOVT PUBS

MANTOR LIBRARY
ATTN: DIR OF LIBRARIES

MARATHON COUNTY PUBLIC LIBRARY
ATTN: LIBRARIAN

MARYLAND UNIVERSITY OF
ATTN: MCKELDIN LIB DOCS DIV

MAUI PUBLIC LIBRARY
ATTN: LIBRARIAN

MEMORIAL HOSP FOR CANCER & ALLIED DISEASES
ATTN: P LIEBERMAN

MEMORIAL SLOAN-KETTERING CANCER CENTER
ATTN: J LAUGHLIN
ATTN: P MARKS

MEMPHIS SHELBY COUNTY PUB LIB & INFO CTR
ATTN: LIBRARIAN

MERCER UNIVERSITY
ATTN: LIBRARIAN

MERCK, SHARP & DOHME INTL
ATTN: A BEARN

MESA COUNTY PUBLIC LIBRARY
ATTN: LIBRARIAN

MIAMI PUBLIC LIBRARY
ATTN: DOCUMENTS DIV

MICHIGAN MEDICAL SCHOOL, UNIV OF
ATTN: J NEEL

MICHIGAN STATE LIBRARY
ATTN: LIBRARIAN

DIRECTORY OF OTHER (CONTINUED)

MICHIGAN, UNIVERSITY OF
ATTN: R CORNELL

MICHIGAN, UNIVERSITY OF
ATTN: F MOORE

MINNESOTA, UNIVERSITY OF
ATTN: J BEARMAN
ATTN: L SCHUMAN
ATTN: LIBRARY

MINOT STATE COLLEGE
ATTN: LIBRARIAN

MISSOURI UNIVERSITY LIBRARY
ATTN: GOVERNMENT DOCUMENTS

MONTANA STATE LIBRARY
ATTN: LIBRARIAN

NASSAU LIBRARY SYSTEM
ATTN: LIBRARIAN

NATL COUNCIL ON RADIATION
ATTN: W SINCLAIR

NATRONA COUNTY PUBLIC LIBRARY
ATTN: LIBRARIAN

NEW HAMPSHIRE UNIVERSITY LIB
ATTN: LIBRARIAN

NEW MEXICO, UNIV OF
ATTN: C KEY
ATTN: R ANDERSON

NEW YORK PUBLIC LIBRARY
ATTN: LIBRARIAN

NEW YORK STATE LIBRARY
ATTN: DOCS CONT CULTURAL ED CTR

NEW YORK STATE UNIV OF
ATTN: LIBRARY DOCS SEC

NEW YORK UNIV MEDICAL CENTER
ATTN: N NELSON

NEW YORK UNIVERSITY
ATTN: A UPTON
ATTN: B POSTERNACK
ATTN: LIBRARY

NEWARK FREE LIBRARY
ATTN: LIBRARIAN

NORTH CAROLINA UNIV AT WILMINGTON
ATTN: LIBRARIAN

NORTH CAROLINA, UNIVERSITY OF
ATTN: LIBRARY FOR DEAN

NORTHERN ARIZONA UNIVERSITY LIB
ATTN: GOVERNMENT DOCUMENTS DEPT

NORTHERN IOWA UNIVERSITY
ATTN: LIBRARY

NORTHERN MICHIGAN UNIV
ATTN: DOCUMENTS

NORTHERN MONTANA COLLEGE LIBRARY
ATTN: LIBRARIAN

NORTHWESTERN MICHIGAN COLLEGE
ATTN: LIBRARIAN

NORTHWESTERN UNIVERSITY
ATTN: H CEMBER

OAK RIDGE ASSOCIATED UNIVERSITIES
ATTN: D LUSHBAUGH
ATTN: E TOMPKINS
ATTN: J TOTTER

OHIO STATE LIBRARY
ATTN: LIBRARIAN

OKLAHOMA DEPT OF LIBS
ATTN: U S GOVT DOCUMENTS

OKLAHOMA, UNIVERSITY OF
ATTN: P ANDERSON

OREGON STATE LIBRARY
ATTN: LIBRARIAN

OREGON, UNIVERSITY OF
ATTN: DOCUMENTS SECTION

OREGON, UNIVERSITY OF
ATTN: B PIROFSKY

PACIFIC NORTHWEST LABORATORY
ATTN: S MARKS

PENNSYLVANIA STATE LIBRARY
ATTN: GOVT PUBS SECTION

PENNSYLVANIA UNIV HOSPITAL
ATTN: S BAUM

PENNSYLVANIA, UNIV OF
ATTN: P NOWELL

PEORIA PUBLIC LIBRARY
ATTN: BUS SCI & TECH DEPT

PHILADELPHIA FREE LIB OF
ATTN: GOVT PUBS DEPT

GREENVILLE COUNTY LIBRARY
ATTN: LIBRARIAN

DIRECTORY OF OTHER (CONTINUED)

PITTSBURGH, UNIV OF
ATTN: E RADFORD
ATTN: LIBRARY

PITTSBURGH, UNIVERSITY OF
ATTN: N WALD

PUBLIC LIB CINCINNATI & HAMILTON COUNTY
ATTN: LIBRARIAN

RAPID CITY PUBLIC LIBRARY
ATTN: LIBRARIAN

READING PUBLIC LIBRARY
ATTN: LIBRARIAN

RHODE ISLAND LIBRARY, UNIVERSITY OF
ATTN: GOVT PUBS OFFICE

ROCHESTER UNIV MEDICAL CTR
ATTN: C ODOROFF
ATTN: G CASARETT

ROCHESTER UNIV OF LIB
ATTN: DOCUMENTS SECTION

ROCHESTER, UNIVERSITY OF
ATTN: L HEMPELMANN

SAINT FRANCIS HOSPITAL
ATTN: R BLAISDELL

SAN ANTONIO PUBLIC LIBRARY
ATTN: BUS SCI & TECH DEPT

SCOTTSBLUFF PUBLIC LIBRARY
ATTN: LIBRARIAN

SCRANTON PUBLIC LIBRARY
ATTN: LIBRARIAN

SILAS BRONSON PUBLIC LIBRARY
ATTN: LIBRARIAN

SIMON SCHWOB MEM LIB
ATTN: LIBRARIAN

SIOUX CITY PUBLIC LIBRARY
ATTN: LIBRARIAN

SOUTH CAROLINA, MEDICAL UNIV OF
ATTN: P LIU

SOUTH DAKOTA STATE LIBRARY
ATTN: FED DOCS DEPT

SOUTHEASTERN MASSACHUSETTS UNIV LIB
ATTN: DOCUMENTS SEC

SOUTHERN ALABAMA, UNIVERSITY OF
ATTN: LIBRARIAN

SOUTHERN CALIFORNIA, UNIV OF
ATTN: J BIRREN

SOUTHERN ILLINOIS UNIVERSITY
ATTN: DOCUMENTS CTR

SOUTHERN MISSISSIPPI UNIV OF
ATTN: LIBRARY

SOUTHERN OREGON COLLEGE
ATTN: LIBRARY

SOUTHERN UTAH STATE COLLEGE LIBRARY
ATTN: DOCUMENTS DEPT

SOUTHWEST MISSOURI STATE COLLEGE
ATTN: LIBRARY

SPOKANE PUBLIC LIBRARY
ATTN: REFERENCE DEPT

SPRINGFIELD CITY LIBRARY
ATTN: DOCUMENTS SECTION

STANFORD UNIV MEDICAL CENTER
ATTN: J BROWN

STANFORD UNIVERSITY
ATTN: L MOSES

STANFORD UNIVERSITY HOSPITAL
ATTN: D DORFMAN

STATE LIBR OF MASS
ATTN: LIBRARIAN

TACOMA PUBLIC LIBRARY
ATTN: LIBRARIAN

TEXAS A & M UNIVERSITY
ATTN: R STONE

TEXAS AT AUSTIN, UNIV OF
ATTN: H SUTTON

TEXAS STATE LIBRARY
ATTN: US DOCS SECTION

TEXAS TECH UNIVERSITY LIBRARY
ATTN: GOVT DOCS DEPT

TEXAS, UNIVERSITY OF
ATTN: C S COOK

TEXAS, UNIVERSITY OF
ATTN: R STALLONES

DIRECTORY OF OTHER (CONTINUED)

TEXAS, UNIVERSITY OF
ATTN: W SUTOW

TEXAS, UNIVERSITY OF
ATTN: G TAYLOR

TOLEDO PUBLIC LIBRARY
ATTN: SOCIAL SCI DEPT

TRENTON FREE PUBLIC LIBRARY
ATTN: LIBRARIAN

TULSA UNIVERSITY, OF
ATTN: LIBRARIAN

UTAH STATE UNIVERSITY
ATTN: LIBRARIAN

UTAH, UNIVERSITY OF
ATTN: LIBRARY

UTAH, UNIVERSITY OF
ATTN: C MAYS
ATTN: E WRENN
ATTN: L LYONS
ATTN: LIBRARY

VANDERBILT UNIVERSITY
ATTN: R QUINN

VERMONT, UNIVERSITY OF
ATTN: DIR OF LIBRARIES

VIRGINIA STATE LIBRARY
ATTN: SERIALS SECTION

VIRGINIA, UNIVERSITY OF
ATTN: PUBLIC DOCUMENTS

WASHINGTON STATE LIBRARY
ATTN: DOCUMENTS SECTION

WASHINGTON, UNIVERSITY OF
ATTN: D THOMPSON

WASHINGTON, UNIVERSITY OF
ATTN: A MOTULSKY

WEST VIRGINIA COLL OF GRAD STUDIES LIB
ATTN: XXXXX

WEST VIRGINIA, UNIVERSITY OF
ATTN: DIR OF LIB REGIONAL

WESTERN WYOMING COMMUNITY COLLEGE LIB
ATTN: XXXXX

WISCONSIN, UNIVERSITY OF
ATTN: ACQUISITIONS DEPT

WISCONSIN, UNIVERSITY OF
ATTN: J CROW

WORCESTER PUBLIC LIBRARY
ATTN: LIBRARIAN

YALE UNIVERSITY
ATTN: DIR OF LIBRARIES

YALE UNIVERSITY SCH OF MEDICINE
ATTN: J MEIGS
ATTN: LIBRARY

END

2-87

DTIC