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TECHNICAL REPORT

Compendium of Proposed NTPR Expedited Processing Groups

Approved for public release; distribution is unlimited

November 2011

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14. ABSTRACT
This report provides detailed descriptions of the 32 proposed Expedited Processing Groups (EPGs) developed using the procedures and methods discussed in DTRA-TR-10-29, *A Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. The discussion of each EPG includes the assumptions used in selecting units and participants included in each group; a description of the activities with potential for radiation exposure; the characteristics of the radiation environments that may have been encountered; and a description of efforts to "maximize" the estimated doses. It provides estimated doses and upper bounds for exposure to external and internal sources of radiation to the whole body and to 20 organs and tissues. The report also provides recommendations about the use of certain organ doses in the expedited dose reconstruction process.

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Nuclear Test Personnel Review, Veterans, Atmospheric Nuclear Weapons Test, Dose Reconstruction, Radiation Dose Assessment

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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 bacquerel (GBq)
degree (angle)	1.745 329 x E -2	radian (rad)
degree Fahrenheit	$t_k = (t^\circ f + 459.67)/1.8$	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		
absorbed dose	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)
ktap	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 dose.

Compendium of Proposed Expedited Processing Groups

1. Introduction

This document complements the technical basis document for the expedited processing of Nuclear Test Personnel Review (NTPR) radiation dose assessments (DTRA, 2011). It provides the specific details of the composition, exposure scenarios, assumptions and parameters of dose calculation, and estimated doses for each Expedited Processing Group (EPG) that has been developed to date.

These introductory sections discuss the approach to preparing an EPG, describe participant activities and groups (units) that are generally excluded from consideration for an EPG, summarize the concepts of highest-dose cohort and maximized dose, and discuss the organization of the specific EPG discussions.

2. Approach to Expedited Processing Groups

The foundations for developing EPGs are contained in widely available information and publications on atmospheric nuclear testing and military participation in those activities from 1945 to 1962, as well as in film badge dosimetry records and previously-completed Radiation Dose Assessments (RDAs) for units and individuals. The process of establishing doses for an EPG consists of the following steps (DTRA, 2011):

- Identify EPG cohorts based on similarity of scenarios of participation activities and exposure pathways of their members.
- Select a “highest-dose cohort” that forms the generic basis for the EPG’s scenario of participation and radiation exposure, potential exposure pathways and related radiation environments.
- Modify dose components for specific exposure pathways using details from the scenarios of exposure of the cohort(s) within the EPG that results in the highest dose for that specific dose component.
- Maximize each dose component, where possible, by using dose parameter values that further overestimate such dose components.
- Use the limiting plausible values of input parameters that further overestimate each dose component.
- Estimate the EPG’s external gamma dose and internal doses to 20 relevant organs using a single combination of the exposure pathways and input parameter values defined in the previous steps. The estimated doses are referred to as the “EPG doses.”

- Calculate upper-bound doses by multiplying the EPG doses by DTRA-approved uncertainty factors. In this calculation, it is also assumed that all dose components are dependent, which further increases upper-bound doses. This is done for all dose components whether based on radiation survey data or film badge dosimetry.

Developed EPGs are reviewed and evaluated to identify opportunities to integrate them into other EPGs or combine them to form an EPG or EPGs with expanded membership, which can lead to enhancements in case-processing efficiency.

DTRA (2011) provides complete details about the criteria for selection of cohorts for inclusion in an EPG and the principles for developing scenario-based dose assessments. In addition, DTRA (2011) describes how successful development of an EPG required that groups or individuals who performed certain activities must be excluded from consideration from many EPGs as discussed in the next section.

3. General Exclusions

Individuals in any of the following categories of activities or groups are to be considered for exclusion from expedited processing because of a potential for high doses. Excluded cases require further review and determination of upper-bound doses. Information needed to make this decision should be in the individual's NTPR case file. Personnel and activities to be excluded are grouped into three general categories of participation as listed in Table 1–Table 3.

4. Characteristics of Exposures and Estimated Dose

EPGs were developed to satisfy the criteria recommended by the Subcommittee on Alternative Methods for Dose Reconstruction (Subcommittee 5) as summarized below (VBDR, 2007).

- The doses should be upper bounds based on dose reconstructions that are more broadly generated and applied than those in individual cases.
- The doses will be high enough to ensure that the reported dose is not less than the veteran's true upper bound (95^{th} percentile) dose.
- The doses almost always will be higher than doses estimated in previous RDAs, thus providing maximum benefit of the doubt to the veteran.
- The reported doses are either well above or well below the dose that could result in a positive finding of service connection for the claimed medical condition, considering age at exposure and age at diagnosis.
- The assigned upper-bound doses for expedited cases should be based on worst-case (i.e., in the direction of overstating exposure) parameters and assumptions, not all of which the veteran may have actually encountered.

Table 1. General Exclusion Guidelines Applicable to Pacific Proving Ground Ship-Based Personnel*

Activity or Cohort
Participation in more than one test series (operation)
Decontamination of any equipment (except for CROSSROADS target ship crews)
Personnel who performed maintenance or repair on contaminated equipment prior to decontamination
Personnel who were topside during one or more fallout events
Personnel whose regular assignment was to a small boat crew
Divers
Crews of cloud-tracking or cloud-sampling aircraft
Involvement in or near heliborne operations (crew members or passengers)
Radioactive sample recovery, handling, or preparation
Personnel who were assigned to support scientific projects, e.g., weapon development projects or effects experiments
Personnel whose regular assignment was to a Radiological Safety (Rad-Safe) unit
Flight drone or sounding rocket operations
Personnel assigned to ships that experienced evaporator or potable water system failures that lead to contaminated drinking water
Shore excursion to any test island.
Consumption of meals or being topside during episodes of descending fallout
Individuals with film badge records and whose total film badge dose is greater than the maximized external dose determined for their respective EPG

* Exclusions apply unless otherwise stated in a specific EPG.

Table 2. General Exclusion Guidelines Applicable to Pacific Proving Ground Land-Based Personnel*

Activity or Cohort
Participation in more than one test series (operation).
Decontamination of aircraft, helicopters, vehicles, or equipment.
Personnel who performed maintenance or repair on contaminated aircraft, helicopters, vehicles, or equipment prior to decontamination.
Personnel whose regular assignment was to a small boat crew.
Divers.
Crews of cloud-tracking, cloud-sampling, or air delivery aircraft.
Involvement in or near heliborne operations (crew members or passengers).
Radioactive sample recovery, handling, or preparation.
Personnel who were assigned to support scientific projects, e.g., weapon development projects or effects experiments (except if participation was with Post-CROSSROADS Bikini Resurvey).
Personnel whose regular assignment was to a Radiological Safety (Rad-Safe) unit.
Flight drone or sounding rocket operations .
Shore excursion to any test island.
Consumption of meals or being topside during episodes of descending fallout.
Individuals with film badge records and whose total film badge dose is greater than the maximized external dose determined for their respective EPG.

* Exclusions apply unless otherwise stated in a specific EPG.

Table 3. General Exclusion Guidelines Applicable to Participants during Testing at the Nevada Test Site*

Activity or Cohort
Participation in more than one test series (operation).
Volunteer Observers.
Participation in decontamination of aircraft, helicopters, vehicles, or equipment.
Personnel who performed maintenance or repair on contaminated aircraft, helicopters, vehicles, or equipment prior to decontamination.
Crews of cloud-tracking, cloud-sampling, or air-delivery aircraft.
Members of helicopter crews.
Radioactive sample recovery, handling, or preparation.
Personnel whose regular assignment was to a Radiological Safety (Rad-Safe) unit.
Personnel who were assigned duties in the forward test area for any reason other than to observe a shot or participate in a maneuver (e.g., Instructor/Control, Signal, Transportation, Engineering, etc.).
Personnel who were assigned to support scientific projects, e.g., weapons development projects and military or civil effects projects.
Personnel whose regular assignment was to a Radiological Safety (Rad-Safe) unit.
Consumption of meals while outside during episodes of descending fallout.
Individuals with film badge records and whose total film badge dose is greater than the maximized external dose determined for their respective EPG.

* Exclusions apply unless otherwise stated in a specific EPG.

As explained in DTRA (2011) these criteria were achieved through the selection of the highest-dose cohort; i.e. the cohort of personnel with the highest external gamma dose among all cohorts included in an EPG. Evaluations were conducted to determine how well the criteria and principles for inclusion in an EPG were satisfied for each candidate group or cohort.

The estimated doses associated with the highest-dose cohort were then maximized by investigating whether alternate scenario components or the use of increased dose calculation parameter values would produce higher external or internal doses. The scenario elements and exposure parameters for other prospective cohorts in the EPG were evaluated to determine if certain scenario components would produce a higher dose than similar components of the highest-dose cohort. If those were found, they were substituted for the component of the highest-dose cohort. In addition, higher values were developed for certain dose calculation parameters compared to the values routinely used in RDAs were implemented. For example, the time spent inside a building was assumed to be in a tent, and breathing rates were increased from the nominal value of 1.2 $m^3 hr^{-1}$ to 2 $m^3 hr^{-1}$. (DTRA, 2011) Details of all these substitutions and parameter increases are discussed in each EPG narrative.

This approach of basing the dose for an EPG on the highest-dose cohort and then maximizing the dose by increasing certain parameters, and applying substitute scenario elements produces estimated doses that are clearly not less than any individual participant's actual dose.

5. Organization of Compendium

This compendium is organized into two major sections of EPG discussions—the first for EPGs for the Oceanic Series, and the second for EPGs for the Series conducted in the Continental United States (CONUS) that occurred mainly at the Nevada Test Site.

6. References

DTRA (Defense Threat Reduction Agency), 2011. *A Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA. October.

VBDR (Veterans' Advisory Board on Dose Reconstruction), 2007. Letter to Director, Defense Threat Reduction Agency. May 7.

Proposed NTPR
Expedited Processing Groups

Oceanic Series

November 2011

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation ARGUS Ship-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation ARGUS Ship-Based Personnel

1. Description of the Expedited Processing Group

The ARGUS Ship-Based Personnel Expedited Processing Group (EPG) consists of the crews of ships assigned to Task Force 88 that participated in Operation ARGUS. The details of ARGUS are described in Jones et al. (1982). Participating ships in Task Force 88 that are included in this EPG are listed in Table 1 (Jones, et al, 1982).

Table 1. Naval Ships that Participated in Operation ARGUS

Ship	Test Area Arrival Date (1958)	Test Area Departure Date (1958)	Task Group	Size
USS ALBEMARLE (AV-5)	Never in test area	Never in test area	Task Group 88.5-Scientific Support Group	503
USS BEARSS (DD-654)	August 25	September 8	Task Group 88.2-Destroyer Group	257
USS COURTNEY (DE-1021)	August 25	September 8	Task Group 88.2-Destroyer Group	160
USS HAMMERBERG (DE-1015)	August 25	September 8	Task Group 88.2-Destroyer Group	163
USS NEOSHO (AO-143)	August 25	September 9	Task Group 88.3-Mobile Logistics Group	287
USS NORTON SOUND (AVM-1)	August 25	September 9	Task Group 88.4, Missile Group.	596
USS SALAMONIE (AO-26)	Never in test area	Never in test area	Task Group 88.3-Mobile Logistics Group	231
USS TARAWA (CVS-40) to include Air Antisubmarine Squadron 32 and Helicopter Antisubmarine Squadron 5	August 25	September 8	Task Group 88.1, Carrier Group	2091
USS WARRINGTON (DD-843)	August 25	September 9	Task Group 88.2-Destroyer Group	271
			Total	4,559

Operation ARGUS was a nuclear weapon test series that was conducted in the South Atlantic Ocean in 1958. The principal objective of ARGUS was to study military implications of high-altitude nuclear detonations. Three nuclear shots were fired during ARGUS, one each on August 27, August 30, and September 6, 1958. Each of the ARGUS warheads was launched on a rocket from the guided missile ship USS NORTON SOUND (AVM-1), had a yield of 1–2 kilotons, and was detonated at an altitude of up to approximately 300 miles (Jones et al., 1982; DTRA, 2008, Appendix B-9).

There are no specific exclusions for this EPG. This EPG include all ARGUS participants who were assigned to any of the nine ships involved in the operation or any land-based participants.

2. Basis of Dose Analysis for Operation ARGUS Ship-Based Personnel

The missiles of the three shots were launched from the USS NORTON SOUND. Of the nine ships involved in Operation ARGUS, seven of the ships were in the general area of the USS NORTON SOUND when the missiles were launched. The other two ships, the USS ALBEMARLE and the USS SALAMONIE were outside of the launch area. The ships in the test area were deployed around the USS NORTON SOUND. At least one ship of the task force was assigned as a weather picket and was more than 100 nautical miles (NMI) from the launch site at the time of each launch. The seven ships in the test area were the following distances below and up range from the detonation as shown in Table 2 (Jones et al., 1982).

Table 2. Distances from Operation ARGUS shots

Shot	Estimated Height of Burst (Miles)*	Estimated Lowest Surface Range from Nearest Task Force Ship to Surface Zero (NMI)
ARGUS 1	~300	275
ARGUS 2	~300	85
ARGUS 3	~300	115

* The exact heights of the bursts could not be found and have been reported at different heights. The height reported is used in Jones et al. (1982).

Due to the horizontal and vertical separations between the ships and the detonations, no radiological exposures were anticipated during the test. However, as a precaution, monitor film badges were issued to the seven ships in the vicinity of the launch with each ship receiving one control badge and ten area monitoring badges. In addition, the weapon handlers and pilots of the four aircraft in flight during each test were issued individual film badges (NRC, 1989). The highest film badge dose was 0.025 rem to a control badge and the highest dose recorded by an individual film badge was 0.01 rem. At the time of the operation, it was concluded that that film badge results were spurious and that no radiation dose was incurred by task force personnel as a result of the nuclear detonations due to the distance from the detonations and the lack of fallout (Jones et al., 1982).

Since ship-based personnel received no external radiation doses from ARGUS detonations, experienced no episodes of descending fallout, and experienced no instances of personnel or equipment contamination during the operation, it was determined that ship-board personnel received no internal doses as a result of any ARGUS detonations (Jones et al., 1982).

3. Summary of EPG Doses and Upper Bounds

For reasons detailed above, there was no potential for exposure for all members of this EPG.

4. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Jones, C. B., M. K. Doyle, L. H. Berkhouse, F. S. Calhoun, E. J. Martin, 1982. *Operation ARGUS 1958.* DNA 6039F. Defense Nuclear Agency, Washington, DC. April 30.

NRC (National Research Council), 1989. *Film Badge Dosimetry in Atmospheric Nuclear Tests*. National Academy Press, Washington, D.C.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure
for Expedited Processing

Operation CROSSROADS
Support Ship-Based Personnel

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

Expedited Processing Group: Operation CROSSROADS Support Ship-Based Personnel

1. Description of the Expedited Processing Group

Operation CROSSROADS is documented in Berkhouse et al. (1984). The CROSSROADS Support Ship-Based Personnel Expedited Processing Group (EPG) consists of the crews of support ships present at Bikini Atoll during the Operation, as listed in Table 1 below (Weitz et al., 1982c), together with the additional elements and excluding the elements listed below.

Table 1. Operation CROSSROADS Support Ships

USS AJAX	USS BOWDITCH	USS GUNSTON HALL	USS MUNSEE	USS SAIDOR
USS ALBEMARLE	USCG BRAMBLE	USS GYPSY	USS NEWMAN K. PERRY	USS SAINT CROIX
USS ALLEN M. SUMNER	USS BULESON	USS HAVEN	USS ONEOTA	USS SAN MARCOS
USS APL 27	USS CEBU	USS HENRICO	USS ORCA	USS SEVERN
USS APPALACHIAN	USS CHARLES P. CECIL	USS HESPERIA	USS OTTAWA	USS SHAKAMAXON
USS APPLING	USS CHICKASAW	USS INGRAHAM	USS PALMYRA	USS SHANGRI-LA
USS ARD 29	USS CHIKASKIA	USS JAMES M. GILLISS	USS PANAMINT	USS SIOUX
USS ARTEMIS	USS CHOWANOC	USS JOHN BLISH	USS PGM 23	USS SPHINX
USS ATA 124	USS CLAMP	USS KENNETH WHTING	USS PGM 24	USS SUNCOCK
USS ATA 180	USS COASTERS HARBOR	USS LAFFEY	USS PGM 25	USS SYLVANIA
USS ATA 185	USS CONSERVER	USS LCI 977	USS PGM 29	USS TELAMON
USS ATA 187	USS CREON	USS LCI(L) 1062	USS PGM 31	USS TOMBIGBEE
USS ATA 192	USS CUMBERLAND SOUND	USS LCI 1067	USS PGM 32	USS TURNER
USS ATR 40	USS CURRENT	USS LCI 1091	USS PHAON	USS WALKE
USS ATR 87	USS DELIVER	USS LOWRY	USS POLLUX	USS WENATCHEE
USS AVERY ISLAND	USS DIXIE	USS LST 388	USS PRESERVER	USS WHARTON
USS BARTON	USS DUTTON	USS LST 817	USS PRESQUE ISLE	USS WIDGEON
USS BAYFIELD	USS ENOREE	USS LST 861	USS QUARTZ	USS WILDCAT
USS BEGOR	USS ETLAH	USS LST 871	USS RECLAIMER	USS YMS 354
USS BENEVOLENCE	USS FALL RIVER	USS LST 881	USS ROBERT K. HUNTINGTON	USS YMS 358
USS BEXAR	USS FLUSSER	USS LST 989	USS ROCKBRIDGE	USS YMS 413
USS BLUE RIDGE	USS FULTON	USS MENDER	USS ROCKINGHAM	USS YMS 463
USS BOTTINEAU	USS FURSE	USS MOALE	USS ROCKWALL	USS YOG 63
USS BOUNTIFUL	USS GEORGE CLYMER	USS MOUNT McKINLEY	USS ROLETTE	

In addition to the ships listed above, the following crews and individuals should be included for expedited processing in this EPG:

- Crews of six remanned target ships that did not receive topside contamination from Shot BAKER: USS BLADEN, USS CORTLAND, USS FILLMORE, USS GENEVA, USS NIAGARA, and USS LCI(L) 615 (Weitz et al., 1982b).
- Crew members of any target ship who did not participate in target ship boardings after Shot BAKER.

The following individuals or units are excluded from expedited processing under this EPG:

- USS ACHOMAWI: unique exposure pathway (faulty evaporator).
- USS COUCAL: unique exposure pathway (weather deck contamination after Shot BAKER).
- USS O'BRIEN: unique exposure pathway (topside fallout after Shot ABLE).
- Crew members involved in flight and drone operations aboard USS SHANGRI-LA and USS SAIDOR
- Individuals who were part of ammunition disposal units at Kwajalein during the Post-CROSSROADS period.

There are approximately 30,000 personnel in this EPG.

2. Basis of Dose Analysis for CROSSROADS Support Ship–Based Personnel

To estimate EPG doses for Operation CROSSROADS support ship-based personnel, an exposure scenario was developed based on activities of the cohort that received the highest external gamma dose and corresponding internal doses.

For this EPG, the activities of crew members of the USS RECLAIMER form the basis for the generic highest-dose cohort scenario for two primary reasons:

- The RECLAIMER crew members received the largest average external gamma dose among all support ship-based personnel.
- The sources of radiation exposure for this cohort are well documented and are similar to those of other support ship-based personnel.

As explained below, several assumptions were added to the documented RECLAIMER scenario (Weitz et al., 1982c) to produce EPG doses. The USS RECLAIMER scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: USS RECLAIMER Crew

To estimate EPG doses for all military personnel assigned to support ships during Operation CROSSROADS, a generic high-sided exposure scenario was develop based on activities of the crew members of the USS RECLAIMER.

The USS RECLAIMER arrived at Bikini Atoll prior to the first shot of the operation and remained in that vicinity until departing for Kwajalein Atoll on September 1, 1946. Missions of the RECLAIMER at Bikini included salvaging target vessels damaged by the detonations, performing emergency repairs, and fighting fires. In addition, the Director of Ship Materiel (DSM) was embarked aboard RECLAIMER to coordinate all salvage operations. The DSM aboard RECLAIMER made the first post-shot inspections of the target array (Berkhouse et al., 1984; Weitz et al., 1982a and 1982c).

Although the largest average external dose was accrued aboard RECLAIMER, there was little potential for the intake of radioactive materials:

- Neither aerosol nor sea spray from the contaminated lagoon would have been present in concentrations sufficient to produce internal doses of more than 0.001 rem for ship-based personnel (Weitz, 1996).
- The airborne concentration of radioactive materials on a support ship from contaminants suspended/resuspended from a nearby target ship after ABLE/BAKER was negligible due to the very small propensity for suspension/resuspension and the distance from the source.
- Contaminants that accumulated on the hull and inside the saltwater piping system of a support ship after BAKER were located in regions generally inaccessible to ship-based personnel and, therefore, were not available for inhalation or ingestion while crewmen performed normal activities aboard ship.

As a result, the primary pathways for internal dose to crew members of support ships occurred during liberty from the inhalation of resuspended fallout, incidental ingestion of contaminated soil and dust while on land, and the ingestion of contaminated water while swimming. The Bikini Island recreational facility opened on August 1, 1946, so the crew of RECLAIMER could have taken liberty there throughout most of August 1946.

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided USS RECLAIMER cohort analysis:

- It was observed that the radiation exposure rates in the engine room and other engineering spaces of the support ships is greater than those found in non-engineering below deck locations (Weitz et al., 1982a). Therefore, crewmen with engineering ratings (i.e., boilermaker, carpenter's mate, fireman, machinist's mate, ship fitter, water tender, engineering officer), who presumably spent more time in areas of the ship with higher exposure rates, are expected to have accrued higher external doses. For this reason, the highest-dose cohort group is further restricted to engineering personnel.

- The internal dose for the crew of the USS BOWDITCH is used instead of the internal dose for the USS RECLAIMER since the highest internal dose for support ship crews at CROSSROADS is attributed to the ship with the longest post-BAKER duration in Bikini Lagoon which is the USS BOWDITCH. The USS BOWDITCH finally departing Bikini on September 27, 1946 and had the longest stay (Berkhouse et al., 1984).
- For the purpose of high-siding the internal dose, the frequency of shore liberty is increased to every second day instead of the Operation CROSSROADS standard of every third day (Berkhouse et al., 1984).
- The breathing rate for outdoor activities is increased from the default value of 1.2 $m^3\ hr^{-1}$ to 2.0 $m^3\ hr^{-1}$. The higher value is based on the assumption of personnel activities during liberty consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al. 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for the CROSSROAD Support Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from contaminated lagoon water while topside aboard ship	Crew members of the USS RECLAIMER were exposed to neutron-activated lagoon water after ABLE and weapon debris-contaminated lagoon water after BAKER.	
Residual radiation from contaminated lagoon water while on liberty	When swimming at the recreational facility during the period August 1 - September 26, 1946, USS BOWDITCH personnel were exposed to contaminated lagoon water.	Liberty is assumed to have occurred every second day instead of the default 3-day frequency.
Residual radiation from contaminants on support ships	While below deck, crew members of the USS RECLAIMER were exposed to radiation emitted from contaminants that had accumulated on the exterior hulls and in the internal saltwater piping systems of the ship.	Duty station for all personnel is assumed to have been in engineering spaces where exposure rates where highest.
Residual radiation from contaminants on nearby target ships	While topside, crew members of the USS RECLAIMER were frequently exposed to contaminated target ships in their vicinity.	
Residual radiation from land-deposited fallout	When on liberty during the period August 1 - September 26, 1946, personnel of USS BOWDITCH were exposed to fallout on Bikini Island.	Liberty is assumed to have occurred every second day instead of the default 3-day frequency.
INTERNAL		
Inhalation of resuspended fallout	When on liberty during the period August 1 - September 26, 1946, personnel of USS RECLAIMER resuspended fallout on Bikini Island.	Breathing rate increased from 1.2 $m^3\ hr^{-1}$ to 2 $m^3\ hr^{-1}$.
Incidental ingestion of contaminated soil/dust	Personnel of USS RECLAIMER incidentally ingested fallout-contaminated soil and dust on Bikini Island during shore liberty.	Extended time at Bikini Atoll until September, 26, 1946, Liberty is assumed to have occurred every second day instead of the default 3-day frequency.
Ingestion of contaminated lagoon water	When swimming at the recreational facility RELCLAIMER personnel ingested contaminated lagoon water.	Extended time at Bikini Atoll until September, 26, 1946, Liberty is assumed to have occurred every second day instead of the default 3-day frequency.

Table 3. Input Parameter Values for the Calculation of the EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Start}$	Earliest date [time] for liberty	Aug 1, 1946 [1030] (DTRA, 2008, Appendix B-1)
$Date_{End}$	Latest date [time] for liberty	Sep 26, 1946 [2359] (based on latest ship departure)
EXTERNAL DOSE		
$Dose_{ExtGam}$	Mean external dose accrued aboard support ship	2.6 rem Derived with XRD code (Raine, 2006)
LibertyInterval	Frequency of taking liberty	2 (every second day)
LibertyTime	Duration of each liberty	3 hours
$Time_{Beach}$	Time spent on beach of Bikini Island [with exposure rates $I_{beach} = (5.47/24)t^{-1.23}$ R/hr] during each liberty	1 hour (DTRA, 2008, Appendix B-1)
$Time_{Inland}$	Time spent inland on Bikini Island [with exposure rate $I_{inland} = (0.90/24)t^{-1.23}$ R/hr] during each liberty	1 hour (DTRA, 2008, Appendix B-1)
$Time_{Swim}$	Time spent swimming during each liberty	1 hour (DTRA, 2008, Appendix B-1)
IO_{Beach}	Initial exposure rate on the beach on Bikini Atoll	0.2279 R hr^{-1} (DTRA, 2008, Appendix B-1)
IO_{Inland}	Initial exposure rate inland on Bikini Atoll	0.0375 R hr^{-1} (DTRA, 2008, Appendix B-1)
λ_{SL}	Decay exponent for shore leave	1.23 (DTRA, 2008, Appendix B-1
INTERNAL DOSE		
BR_{Bikini}	Breathing rate during liberty	2.0 m^3 hr^{-1}
$K_{Bikini}(t)$	Time-dependent resuspension factor	$K_{Bikini}(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (DTRA, 2010, SM ID01)
q_{ing}	Ingestion rate of water while swimming	0.1 l hr^{-1} (DTRA, 2008, Appendix B-1)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the CROSSROAD support ship-based personnel are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for CROSSROADS Support Ship-Based Personnel

External Doses	**EPG Dose (rem)**		**Upper Bound EPG Dose (rem)**	
Residual Gamma Radiation	3		9	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	<0.001	0.003	0.009
Bone Surface	0.2	0.009	2	0.09
Brain	<0.001	<0.001	0.003	0.005
Breast	<0.001	<0.001	0.003	0.006
Stomach Wall	<0.001	0.004	0.003	0.04
Small Intestine Wall	<0.001	0.008	0.003	0.08
Upper Large Intestine Wall	<0.001	0.04	0.003	0.4
Lower Large Intestine Wall	<0.001	0.09	0.003	0.9
Kidney	<0.001	0.002	0.006	0.02
Liver	0.03	0.002	0.3	0.03
Extra-Thoracic Region	0.002	0.02	0.02	0.2
Lung	0.003	0.04	0.03	0.4
Muscle	<0.001	<0.001	0.003	0.009
Pancreas	<0.001	0.001	0.003	0.01
Red Marrow	0.007	0.004	0.07	0.04
Spleen	<0.001	<0.001	0.003	0.008
Testes	0.002	<0.001	0.02	0.007
Thymus	<0.001	<0.001	0.003	0.007
Thyroid	<0.001	0.2	0.003	2
Urinary Bladder Wall	<0.001	0.003	0.003	0.03

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 4 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 5. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. Cancer Cases not Recommended for Expedited Processing for CROSSROADS Support Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	11
Total EPG upper-bound dose below but close to the screening dose		
Liver	Liver	10

6. References

Berkhouse, L., Davis, S. E., Gladeck, F. R., Hallowell, J. H., Jones, C. B., Martin, E. J., McMullan, F. W., and Osborne, M. J., 1984. *Operation CROSSROADS: 1946*. DNA 6032F, Defense Nuclear Agency, Washington, D.C. May 1.

DTRA (Defense Threat Reduction Agency), 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment - Nuclear Test Personnel Review Program, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Raine, D. A. III, 2006. *XRD User's Guide*. Science Applications International Corporation, McLean, VA.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4.* DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R., Stuart, J., Muller, E., Thomas, C., Knowles, M., Landay, A., Klemm, J., and Goetz, J., 1982a. *Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS, Volume I - Basic Report*. DNA-TR-82-05-V1, Defense Nuclear Agency, Washington, D.C. March 3.

Weitz, R., Stuart, J., Muller, E., Thomas, C., Knowles, M., Landay, A., Klemm, J., and Goetz, J., 1982b. *Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS, Volume II – (Appendix A) Target Ships*. DNA-TR-82-05-V2, Defense Nuclear Agency, Washington, D.C. March 3.

Weitz, R., Stuart, J., Muller, E., Thomas, C., Knowles, M., Landay, A., Klemm, J., and Goetz, J., 1982c. *Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS, Volume III – (Appendix B) Support Ships*. DNA-TR-82-05-V3, Defense Nuclear Agency, Washington, D.C. March 3.

Weitz, R. L., 1996. *Internal Dose from Sea Aerosol Intake*. Memorandum, Science Applications International Corporation, McLean, VA.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation CROSSROADS Target Ship-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation CROSSROADS Target Ship-Based Personnel

1. Description of the Expedited Processing Group

Operation CROSSROADS is thoroughly documented in Berkhouse et al. (1984). The CROSSROADS Target Ship-Based Personnel Expedited Processing Group (EPG) consists of the crews of vessels utilized as target ships during CROSSROADS, as listed in Table 1 (Weitz et al., 1982b), minus the excluded elements listed below the table.

Table 1. Operation CROSSROADS Target Ships

USS ANDERSON	USS DAWSON	USS LCT 705	USS LCT 1237	USS PENNSYLVANIA
USS ARDC 13	USS FALLON	USS LCT 746	USS LSM 60	USS PENSACOLA
USS ARKANSAS	USS GASCONADE	USS LCT 812	USS LST 52	PRINZ EUGEN
USS BANNER	USS GILLIAM	USS LCT 816	USS LST 125	USS RALPH TALBOT
USS BARROW	USS HUGHES	USS LCT 818	USS LST 133	USS RHIND
USS BRACKEN	USS INDEPENDENCE	USS LCT 874	USS LST 220	SAKAWA
USS BRISCOE	USS LAMSON	USS LCT 1013	USS LST 545	USS SALT LAKE CITY
USS BRULE	USS LCI 327	USS LCT 1078	USS LST 661	USS SARATOGA
USS BUTTE	USS LCI 329	USS LCT 1112	USS MAYRANT	USS STACK
USS CARLISLE	USS LCI 332	USS LCT 1113	USS MUGFORD	USS TRIPPE
USS CARTERET	USS LCI 620	USS LCT 1114	USS MUSTIN	USS WAINWRIGHT
USS CATRON	USS LCI(L) 549	USS LCT 1115	NAGATO	USS WILSON
USS CONYNGHAM	USS LCT 412	USS LCT 1175	USS NEVADA	USS YO 160
USS CRITTENDEN	USS LCT 414	USS LCT 1187	USS NEW YORK	USS YOG 83

Five target ships sank without being reboarded after Shot ABLE (USS ANDERSON, USS CARLISLE, USS GILLIAM, USS LAMSON, and SAKAWA) and six after Shot BAKER (USS ARDC 13, USS ARKANSAS, USS LSM 60, NAGATO, USS SARATOGA, and USS YO 160). Crews of sunken target ships were often splintered and reassigned to various ships, including other target ships. These crew members are therefore included in the present EPG unless it is known that they did not participate in post-BAKER target ship boarding activities (see second exclusion listed below).

The following individuals and units are excluded from expedited processing under this EPG:

- Crews of six remanned target ships that did not receive topside contamination from Shot BAKER: USS BLADEN, USS CORTLAND, USS FILLMORE, USS GENEVA, USS NIAGARA, and USS LCI(L) 615. These personnel are included in the CROSSROADS Support Ship-Based Personnel EPG.
- Crew members of any target ships who did not participate in target ship boardings after Shot BAKER – these personnel are included in the CROSSROADS Support Ship-Based.

- Crew members of any target ships who were subsequently assigned to Ammunition Disposal Units and participated in ammunition unloading at Kwajalein.
- Crews of target submarines.

There are approximately 8000 personnel in this EPG.

2. Basis of Dose Analysis for CROSSROADS Target Ship-Based Personnel

To estimate EPG doses for CROSSROADS target ship-based personnel, an exposure scenario was developed based on activities of the group that received the highest external residual radiation dose. This cohort is referred to as the "highest-dose cohort."

For this EPG, the activities of the engineering team assigned to the USS CARTERET for the basis for the generic highest-dose cohort scenario (DTRA, 2008, Appendix B-1) for the following reasons:

- A thorough examination of Navy NTPR target ship boarding dose reconstructions, performed circa 1983-5, has identified the highest-dose cohort among target ship-based personnel at CROSSROADS as members of an engineering team assigned to the target ship USS CARTERET.
- Although this cohort stands out as having the largest external gamma dose, it is not unique external gamma dose.
- Reboarding teams on other target ships (e.g., USS STACK, USS MUGFORD, USS SALT LAKE CITY) received only slightly smaller external doses.

As explained below, several dose components and assumptions were added to the documented USS CARTERET reboarding scenario (NNTPR, 1983) to produce EPG doses. The basic scenario of participation and radiation exposure of the USS CARTERET is described in Section 3 followed by a description of the additional assumptions in Section 4.

3. Highest-Dose Cohort Scenario: USS CARTERET Engineering Team

To estimate EPG doses for all military personnel assigned to CROSSROADS target ships, a generic high-sided exposure scenario was developed based on activities of the USS CARTERET. USS CARTERET was in a target array of both shots. Its crew evacuated to the attack transport USS BEXAR on June 30 in preparation for Shot ABLE, and returned to USS CARTERET after the target ship had been declared free of radioactivity by radiation safety personnel on July 2. The crew reboarded USS BEXAR on July 24 in preparation for the BAKER test. Although USS BEXAR did not reenter Bikini Lagoon until the morning of July 30, some crew members returned earlier to participate in an initial reboarding of USS CARTERET on July 29. Subsequent boardings of the target ship took place during August 1-18 for decontamination and painting. While most of the crew was billeted on USS BEXAR during this period, the commanding officer and a skeleton crew of engineers remained aboard USS CARTERET continuously during August 3-11 to operate the ship's boilers. This engineering team also stood watch and supported decontamination activities by scraping and repainting the deck. The team performed these duties, operating mostly topside, until ordered by radsafe personnel to leave USS CARTERET on the morning of August 11. Crew members were next allowed aboard the ship on August 16-18. The USS CARTERET crew transferred from USS BEXAR to USS GEORGE CLYMER on August 20 for transportation to the Continental United States (NNTPR, 1983; Berkhouse et al., 1984).

As indicated above, the crew members of USS CARTERET and the other target ship were billeted aboard one or more "support" ships during and after each shot, but they typically reboarded the target ship to conduct inspections, decontamination, and repairs. While billeted aboard a support ship, a target ship crewman was exposed to residual radiation from contaminants suspended in the lagoon water, deposited on nearby target ships, and retained on the exterior hull and in internal saltwater piping system of the billet ship itself (Weitz et al., 1982a). When aboard his parent target ship, the crewman was exposed to neutron activation products after Shot ABLE and deposited weapon debris after Shot BAKER. While on liberty, he was exposed to residual radiation from the contaminated seawater and from radionuclides deposited as fallout or rainout on Bikini Island.

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were incorporated into the generic high-sided analysis:

- While aboard the billet ships USS BEXER and USS GEORGE CLYMER, the members of subject engineering team are assumed to have spent their below-deck time in engineering spaces, where the radiation exposure rates were greater than those found in other below-deck locations.
- Members of engineering team are assumed to have remained topside while aboard USS CARTERET.
- An enhanced factor of 10^{-5} m^{-1}, instead of the default value of 10^{-6} m^{-1}, is used to characterize the resuspension that resulted from paint chipping and similar decontamination activities prior to August 12, 1946. After August 12, 1946 the focus on target ship reboarding shifted from decontamination to inspection and repair; the default value of resuspension factor is used for boardings that took place on or after that date.
- Members of engineering team are assumed to have chipped paint 4 hours per day during August 3-11, and to have ingested 1 cm^2 of contaminated paint per hour of chipping.
- The breathing rate during liberty is increased from the default value of 1.2 m^3 hr^{-1} to 2.0 m^3 hr^{-1}.
- Team members are assumed to have taken liberty every second day the facility was available to them (August 1-2 and August 11-20).

Exposure pathways for the EPG scenario are described in Table 2. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for the CROSSROADS Target Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from contaminated lagoon water while topside aboard ship	When topside on billet ships, crew members of USS CARTERET were exposed to neutron-activated lagoon water after Shot ABLE and weapon debris-contaminated lagoon water after Shot BAKER.	
Residual radiation from contaminated lagoon water while on liberty.	When swimming during liberty, crew members of USS CARTERET were exposed to contaminated lagoon water.	Liberty is assumed to have occurred every second day instead of the default 3-day schedule.
Residual radiation from contaminants on billet ships	While below decks on billet ships, crew members of USS CARTERET were exposed to the external radiation from contamination that had accumulated on the exterior hulls and in the internal saltwater piping systems of those ships.	Assumed that engineering team occupied engineering spaces 16 hours per day while below deck on billet ship.
Residual radiation from contaminants on target ships	While aboard USS CARTERET, crew members were exposed to external radiation due to radioactive contaminants deposited topside and below deck.	Assumed that engineering team remained topside while on target ship.
Residual radiation from land-deposited fallout	Personnel on liberty were exposed to residual radiation from fallout due to Shots ABLE and BAKER on Bikini Island.	Liberty is assumed to have occurred every second day instead of the default 3-day schedule.
INTERNAL		
Inhalation of resuspended fallout while aboard target ship	Personnel on USS CARTERET inhaled contaminants that were resuspended during decontamination and similar shipboard activities.	Resuspension factor increased from 10^{-6} to 10^{-5} m^{-1} for topside work on target ship.
Inhalation of resuspended fallout during shore liberty	Personnel on liberty inhaled resuspended fallout while on Bikini Island.	Breathing rate increased from 1.2 to 2 m^3 hr^{-1} while on liberty.
Incidental ingestion of contaminated soil/dust	Personnel incidentally ingested fallout-contaminated soil and dust while on Bikini Island.	Liberty is assumed to have occurred every second day instead of the default 3-day schedule.
Ingestion of contaminated lagoon water	Personnel on liberty ingested contaminated lagoon water while swimming.	Liberty is assumed to have occurred every second day instead of the default 3-day schedule.
Ingestion of contaminated paint chips	Chipping paint in preparation for repainting topside areas of target ships was a common decontamination procedure; some ingestion of chipped paint is likely.	Ingestion of 1 cm^2 of contaminated paint chips per hour spent scraping on target ship.

Table 3. Input Parameters Values for the Calculation of EPG Doses

Parameter	Definition	Value
EXTERNAL DOSE		
$DoseDet_{OperWater}$ $DoseDet_{OperShipCon}$	Mean external doses accrued while aboard support ships from exposures to radionuclides deposited in water and on target ships (first parameter) and from ship contamination (second parameter).	0.180 rem 0.352 rem (Derived with XRD code [Raine, 2006]; Weitz et al., 1982c)
$Tstart_{TS}$ $Board_{TS}$	Target ship boarding dates (1946) and hours aboard for each date	July 29 (0.25 hr), Aug 1 (0.17), Aug 2 (3), Aug 3 (16), Aug 4-10 (continuous), Aug 11 (10), Aug 16 (8), Aug 17 (9), Aug 18 (9) (NNTPR, 1983)
$IntDa_{TS}$	Topside exposure rates on USS CARTERET	per Figure A-8, Weitz et al., 1982b
λ_{SL}	Decay exponent for shore liberty	1.23 (DTRA, 2008, Appendix B-1)
λ_{SB}	Decay exponent for ship reboarding	1.3 (DTRA, 2008, Appendix B-1)
$Date_{StartSL1} - Date_{EndSL1}$ $Date_{StartSL2} - Date_{EndSL2}$	Dates during which liberty was available	1-2 Aug 46 11-20 Aug 46
$Frac_{SL}$	Fraction of time spent on liberty Frequency of taking liberty	3/(24x2) = 0.0625 3 hours every second day
$LibertyTime$	Duration of each liberty	3 hours
$Frac_{Beach}$	Fraction of time spent on beach of Bikini Island [with exposure rate $I_{beach} = (5.47/24)t^{-1.23}$ R/hr] during each liberty	1/3 (DTRA, 2008, Appendix B-1)
$Frac_{Inland}$	Fraction of time spent inland on Bikini Island [with exposure rate $I_{inland} = (0.90/24)t^{-1.23}$ R/hr] during each liberty	1/3 (DTRA, 2008, Appendix B-1)
$Frac_{Swim}$	Fraction of time spent swimming during each liberty	1/3 (DTRA, 2008, Appendix B-1)
INTERNAL DOSE		
$GSMF_{Ship}$	Gamma Source Modification Factor for USS CARTERET	3.14 (mean value for APA) (Weitz, 2009)
K_{Ship}	Resuspension factor for topside on USS CARTERET	10^{-5} m^{-1}
BR_{Nom}	Breathing rate while aboard USS CARTERET and during liberty	2.0 m^3 hr^{-1}
$Paint_{TS}$	Hours per day spent chipping paint on USS CARTERET during Aug 3-11	4.0
q_{PC}	Square centimeters of paint ingested per hour of scraping	1.0
$K_{Bikini}(t)$	Time-dependent resuspension factor	$K_{Bikini}(t) = 10^{-5} \times e^{-0.01 \times \frac{t}{24}} + 10^{-9} \quad \mathrm{m}^{-1}$ (DTRA, 2010, SM ID01)
q_{ing}	Ingestion rate of water while swimming	0.1 L hr^{-1}
q_{intake}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)

Table 3. Input Parameters Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the CROSSROADS target ship-based personnel are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Operation CROSSROADS Target Ship-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	3		9	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.009	0.03	0.09	0.3
Bone Surface	5	0.3	47	3
Brain	0.009	0.02	0.09	0.2
Breast	0.009	0.02	0.09	0.2
Stomach Wall	0.009	0.09	0.09	0.9
Small Intestine Wall	0.009	0.2	0.09	2
Upper Large Intestine Wall	0.009	0.8	0.09	8
Lower Large Intestine Wall	0.009	2	0.09	19
Kidney	0.02	0.04	0.2	0.4
Liver	1	0.07	11	0.7
Extra-Thoracic Region	0.05	0.9	0.5	9
Lung	0.1	2	1	19
Muscle	0.009	0.03	0.09	0.3
Pancreas	0.009	0.03	0.09	0.3
Red Marrow	0.3	0.09	3	0.9
Spleen	0.009	0.03	0.09	0.3
Testes	0.07	0.02	0.7	0.2
Thymus	0.009	0.03	0.09	0.3
Thyroid	0.009	5	0.09	45
Urinary Bladder Wall	0.009	0.06	0.09	0.6

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 4 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 5. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. Cancer Cases not Recommended for Expedited Processing for CROSSROADS Target Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Bile Duct	Liver	20
Bone	Bone Surface	59
Gall Bladder	Liver	20
Liver	Liver	20
Thyroid	Thyroid	53

6. References

Berkhouse, L., Davis, S. E., Gladeck, F. R., Hallowell, J. H., Jones, C. B., Martin, E. J., McMullan, F. W., and Osborne, M. J., 1984. *Operation CROSSROADS: 1946*. DNA 6032F, Defense Nuclear Agency, Washington, D.C. May 1.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment – Nuclear Test Personnel Review Program, Revision 1.2.* , Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment - Nuclear Test Personnel Review Program, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

NNTPR (Navy Nuclear Test Personnel Review Team), 1983. *NNTPR Radiation Dose Assignment for Crew of USS CARTERET (APA-70)*. October 9 (original) and 18 (supplement).

Raine, D. A. III, 2006. *XRD User's Guide*. Science Applications International Corporation, McLean, VA.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R.L., 2009. *Formulation of the Gamma Source Modification Factor (GSMF) for Ship-based Applications*. NTPR-TM-09-04, Defense Threat Reduction Agency, Fort Belvoir, VA.

Weitz, R., Stuart, J., Muller, E., Thomas, C., Knowles, M., Landay, A., Klemm, J., and Goetz, J., 1982a. *Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS, Volume I - Basic Report*. DNA-TR-82-05-V1, Defense Nuclear Agency, Washington, D.C. March 3.

Weitz, R., Stuart, J., Muller, E., Thomas, C., Knowles, M., Landay, A., Klemm, J., and Goetz, J., 1982b. *Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS, Volume II – (Appendix A) Target Ships*. DNA-TR-82-05-V2, Defense Nuclear Agency, Washington, D.C. March 3.

Weitz, R., Stuart, J., Muller, E., Thomas, C., Knowles, M., Landay, A., Klemm, J., and Goetz, J., 1982c. *Analysis of Radiation Exposure for Naval Units of Operation CROSSROADS, Volume III – (Appendix B) Support Ships*. DNA-TR-82-05-V3, Defense Nuclear Agency, Washington, D.C. March 3.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation CROSSROADS Land-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation CROSSROADS Land-Based Personnel

1. Description of the Expedited Processing Group

The CROSSROADS Land-Based Personnel Expedited Processing Group (EPG) consists of individuals who participated in Operation CROSSROADS who were assigned to and resided on the Pacific islands of Kwajalein, Ebeye, Roi-Namur, Enewetak, Wake, Tarawa, and Majuro as stated in Berkhouse et al. (1984). Individuals with exposure types identified below as exclusions are processed separately. The details of Operation CROSSROADS can be found in Berkhouse et al. (1984). Specific to the CROSSROADS Land-Based Personnel EPG, air support operations were staged out of Kwajalein and Enewetak Islands. Weather monitoring stations were located on several distant islands (Berkhouse et al., 1984 and DTRA, 2008, Appendix B-1).

Approximately 2,600 personnel were assigned to Kwajalein, Enewetak, and distant islands during Operation CROSSROADS. The majority of the personnel were stationed on Kwajalein Island. Except for the Marine Corps Detachment, land participants were Army-Air Force personnel who were assigned to Task Group 5.1 as listed in Table 1 (Berkhouse et al., 1984).

Table 1. Operation CROSSROADS Land-Based Units

Unit	Locations	Unit Size
Task Unit 1.5.1 (Tactical Operations Unit)	Kwajalein Island	367
Task Unit 1.5.2 (Army Air Photographic Unit)	Kwajalein Island	412
Task Unit 1.5.3 (Instrumentation and Test Requirements Unit)	Enewetak Island	450
Task Unit 1.5.4 (Air Transport Unit)	Kwajalein Island	55
Task Unit 1.5.5 (Air Service Unit)	Kwajalein and Enewetak Islands	686
Task Unit 1.5.7 (Army Air Weather Reconnaissance Unit)	Kwajalein Island	56
Task Unit 1.5.8 (Air Orientation Unit)	Kwajalein Island	27
Task Unit 1.5.9 (Air-Sea Rescue Unit)	Enewetak Island	48
Task Unit 1.5.10 (Headquarters, Air Unit)	Kwajalein Island	139
Task Unit 1.5 (others)	Kwajalein Island	249
Marine Corps Detachment	Enewetak Island	107
	Total	2,596

The following individuals or activities are excluded from expedited processing under this EPG:

- Individuals who participated in decontamination of target ships moored at Kwajalein Island.
- Individuals who participated in the towing of target ships to Kwajalein Island.

- Individuals who participated in small boat operations involving contaminated target or support ships moored at Kwajalein Island.
- Individuals who performed surveys, construction, or experiments on Bikini Atoll after Shot ABLE.
- Individuals who participated in unloading, inspecting, handling, moving, and decontaminating ammunition on target ships moored at Kwajalein Island.
- Individuals who participated in the handling of contaminated clothing, waste, or equipment created during ammunition inspection and unloading operations at Kwajalein Island.

2. Basis of Dose Analysis for Operation CROSSROADS Land-Based Personnel

To estimate EPG doses for CROSSROADS land-based personnel, an exposure scenario was developed based on activities of the cohort that received the highest external gamma dose. This cohort is referred to as the "highest-dose cohort."

For this EPG, the activities of those members of Task Unit 1.5.5 that were assigned to Enewetak Island who returned to the United States on the USS APPLING form the basis for the exposure scenario of the highest-dose cohort for two primary reasons:

- Task Group 1.5.5 members received the largest external gamma dose among all land-based personnel due to being on the troop transport ship with the highest exposure rate due to residual radioactive contamination on the ship.
- The sources of radiation exposure for this cohort are well documented and are similar to those of other land-based personnel during CROSSROADS

As explained below, several dose components and assumptions were added to the documented TU 1.5.5 scenario to produce EPG doses. The TU 1.5.5 scenario is described directory below followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Task Unit 1.5.5 (Enewetak)

The cohort with the largest external dose among members of the CROSSROADS land-based personnel EPG is TU 1.5.5 who were assigned to Enewetak Island and who returned to the U.S. on the USS APPLING. The members of the cohort arrived at Enewetak Island prior to the first shot of CROSSROADS, departed on August 7, 1946 aboard the USS APPLING, and debarked the USS APPLING on August 22, 1946 in San Francisco (U.S. Navy, 1946). The members of the TU 1.5.5 were only exposed to residual radiation during their time on the transport ship while travelling back to the United States. These personnel, along with other members of TG 1.5, were not exposed to other sources of radiation for the following reasons (CJTF1, 1946; Berkhouse et al., 1984 and DTRA, 2008, Appendix B-1):

- Land-based personnel were beyond the range of any initial radiation to include initial gamma and neutron radiations (Weitz and Egbert, 2010).

- The Islands of Kwajalein and Enewetak along with more distant islands did not receive any fallout radiation from Shots ABLE and BAKER nor did the islands receive any contaminated lagoon water from Bikini Atoll. There was no residual radiation on any of the islands from previous tests since CROSSROADS was the first atomic test in the Pacific (Berkhouse et al., 1984).
- After Shot BAKER, contaminated target ships were towed from Bikini Atoll to Kwajalein Island for removal of ammunition and for storage. However, only personnel who boarded the ships or conducted small boat operations near the ships were exposed to residual radiation from the contaminated target ships at Kwajalein Island. No ships were towed to Enewetak Island or to any of the other island (Berkhouse et al., 1984; Phillips, et al., 1985).
- Potentially contaminated aircraft landed on Kwajalein and Enewetak Islands. Only those individuals who were aircraft crew or who were assigned to aircraft decontamination or maintenance could have been exposed to the residual contamination on the aircraft. These cases would be referred to further evaluation (Berkhouse et al., 1984).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided TU 1.5.5 cohort analysis:

- It is assumed that members of TG 1.5.5 who sailed on the USS APPLING spent 16 hours a day below deck and eight hours a day above deck while onboard. Assuming more time below deck increase the dose to the EPG members from hull and ship piping contamination.
- It is assumed that members of TG 1.5.5 who sailed on the USS APPLING did not leave the ship while it was moored in Pearl Harbor, Hawaii before continuing on to the continental United States.

Exposure pathways for the EPG scenario are described in Table 2. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for Operation CROSSROADS Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual salt water piping contamination	Members of TU 1.5.5 who sailed on the USS APPLING were exposed to residual radiation from contamination in the salt water piping system. .	16 hours below deck per day instead of 14.4 hours below deck.
Residual hull contamination	Members of TU 1.5.5 who sailed back to the U.S. on the USS APPLING were exposed to residual radiation from contamination on the hull of the ship.	16 hours below deck per day instead of 14.4 hours below deck.
INTERNAL		
None		

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{boarding}$	Date [time] of boarding the USS APPLING	7 Aug 1946 [1500]
$Date_{debarking}$	Date [time] of debarking from the USS APPLING	22 Aug 1946 [1500]
EXTERNAL DOSE		
F_{os}	Fraction of time spent topside	0.33 (= 8/24)

5. Summary of EPG Doses and Upper Bounds

The EPG external dose and corresponding upper-bound dose for the CROSSROADS Land-Based Personnel EPG are summarized in Table 4. The EPG external dose and the upper-bound external gamma dose from residual radiation were calculated using the XRD software (Raine, 2006). There was no potential for exposure to internally-deposited radionuclides for this group.

Table 4. External and Internal Doses and Upper-Bounds for CROSSROADS Land-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual gamma radiation	0.03		0.09	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
All Organs	There was no potential for exposure to internally-deposited radionuclides for this group.			

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

6. References

Berkhouse, L., Davis, S. E., Gladeck, F. R., Hallowell, J. H., Jones, C. B., Martin, E. J., McMullan, F. W., and Osborne, M. J., 1984. *Operation CROSSROADS: 1946.* DNA 6032F, Defense Nuclear Agency, Washington, D.C. May 1.

CJTF1 (Commander Joint Task Force One), 1946. *Report on Atomic Bomb Tests ABLE and BAKER (Operation CROSSROADS).* WT-206, Joint Task Force One, Marshall Islands.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *An Expedited Approach to NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.TBD.

Phillips, R., Klemm, J., and Goetz, J., 1985. *Internal Dose Assessment-Operation COSSROADS*. DNA-TR-84-119, Defense Nuclear Agency, Washington, D.C. October 30.

Raine, D.A. 2006. *XRD User's Guide*. Defense Threat Reduction Agency, Fort Belvoir, VA. June 21.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1), Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

U.S. Navy, 1946, Deck Log Book for USS APPLING, August 1-31.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

USS BRUSH Crew (February 25–27, 1947)

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: USS BRUSH Crew (February 25–27, 1947)

1. Description of the Expedited Processing Group

The USS BRUSH Crew Expedited Processing Group (EPG) consists of the approximately 250-man crew of the destroyer USS BRUSH (DD 745) while the ship was present at Kwajalein Atoll February 25–27, 1947 (Berkhouse et al., 1984). Although specific activities of the crew members were different, activities that resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation resulting in exposure were common among crew members. Therefore, it is reasonable to include the crew of the USS BRUSH in a single EPG.

Operation CROSSROADS consisted of two 21-kT nuclear tests, ABLE and BAKER, conducted at Bikini Atoll on July 1 and July 25, 1946, respectively. More than 80 unmanned "target" ships were anchored in Bikini Lagoon for each test. In late August and early September, 1946, approximately 60 target ships that had survived the tests at Operation CROSSROADS were taken to Kwajalein Atoll, about 210 nautical miles southeast of Bikini Atoll. A primary mission at Kwajalein was to remove and dispose of ammunition that had been stored on target ships. Personnel also boarded target ships at Kwajalein to perform limited maintenance and security tasks intended to keep the ships seaworthy. There were approximately 30 former target ships anchored in Kwajalein Lagoon at the time of USS BRUSH's visit (Berkhouse et al., 1984).

The following individuals are excluded from expedited processing under this EPG:

- Personnel who transferred to USS BRUSH after the ship's departure from Kwajalein Atoll on February 27, 1947.

2. Basis of Dose Analysis for USS BRUSH Crew

To estimate EPG doses for all USS BRUSH crew members, an exposure scenario was developed based on activities of personnel with highest potential for dose from exposure to external residual radiation and the corresponding internal doses. These crewmen are referred to as the "highest-dose cohorts."

For this EPG, the activities of USS BRUSH crew members are those who participated in all excursions to target ships at Kwajalein Atoll for the basis for the generic highest-dose cohort scenario for the primary reason that that were present in the areas of highest possible doses.

As explained below several dose components and assumptions were added to the documented USS BRUSH scenario to produce EPG doses. The USS BRUSH scenario is described directly below, followed by a listing of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: USS BRUSH Crew Members who Participated in Excursions to Target Ships

To estimate EPG doses for all personnel assigned to the USS BRUSH, a generic high-sided exposure scenario was developed based on activities of the crew members who participated in excursions to target ships. The high-sided generic scenario is based on interviews with various USS BRUSH crew members unless otherwise attributed.

While USS BRUSH was anchored in the lagoon, a whale boat was dispatched from the ship for approximately four trips to nearby target ships to collect souvenirs. These excursions involved about 40 crew members. The average topside radiation exposure rate of all target ships present at Kwajalein at that time was 0.0022 R hr^{-1} (Phillips et al., 1985). Souvenir hunting was terminated on orders from the shore base for USS BRUSH personnel to stop boarding target ships. The contaminated souvenirs, including a wooden helm, chronometers, boiler gauges, brass levers, knobs, and nameplates, were transported to and brought aboard USS BRUSH, then placed in the mess area where they were viewed by crew members. The quantity of souvenirs was sufficient to cover two 10-man tables. These souvenirs were sold or bartered, and subsequently distributed throughout the living spaces of the ship.

USS BRUSH got underway from Kwajalein on the morning of February 27, 1947, and proceeded to Pearl Harbor, Hawaii, arriving there on March 11, 1947 (USS BRUSH, 1947).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions are added to the already high-sided USS BRUSH cohort analysis:

- Members of the highest-dose cohort are assumed to have 4 hours on each of four target ships. Given the briefness of USS BRUSH's stay to Kwajalein, 16 hours is considered the maximum amount of time that could have been devoted to souvenir gathering.
- All souvenirs are assumed to have been taken from topside locations on target ships and are assumed to be contaminated to the same levels as on the parent vessels.
- The gamma source modification factor (GSMF) of the target ships boarded is 4.06.
- The resuspension factor on target ships is 10^{-5} m^{-1} instead of the standard value of 10^{-6} m^{-1} prescribed in Phillips et al., 1985, due to the mechanical disturbance created by the expedient removal of souvenirs from contaminated surfaces.
- The breathing rate during excursions to target ships is 2.0 m^3 hr^{-1} instead of the standard value of 1.2 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average breathing rate.
- Highest-dose cohort members spent 2 hours at a distance of 1 m from the entire collection of souvenirs while transporting them to USS BRUSH in the whale boat and while viewing them on display in the mess area. This is considered a high-sided duration for viewing the souvenirs.

- The souvenirs brought aboard USS BRUSH had a total surface area of 10 m^2.
- Through handling, contaminants on souvenirs are assumed to have transferred to a crew member's hands to the extent that the surface activity density thus accrued on the palms and palm-side fingers was equal to 30 percent of the surface activity density that was originally on the souvenirs. Half of the amount of contaminant material on the palm sides of the hands is assumed to have subsequently transferred to the mouth and ingested. These conservative souvenir-to-hand and hand-to-mouth transfer factors are based on a survey of the relevant literature (Weitz, 2011).
- The souvenirs are assumed to have eventually dispersed among the crew members and put into footlockers or duffle bags that were distributed throughout the living spaces of USS BRUSH, an area estimated at 500 m^2; the average exposure rate in these spaces decreased only though radiological decay.
- Cohort members spent 2/3 of their time below decks in this radiation environment (e.g., while dining and sleeping) from late February 1947 until transferring from USS BRUSH one year later.

Exposure pathways for the EPG scenario are described in Table 1. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 2.

Table 1. Exposure Pathways for the USS BRUSH Crew Members

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from contaminants on target ships	During excursions to target ships, USS BRUSH crew members who collected souvenirs were exposed to residual radiation emitted from contaminants on/in contaminated target ships.	
Residual radiation from contaminants on souvenirs	While in the proximity of scavenged souvenirs, USS BRUSH crew members who collected souvenirs were exposed to residual radiation emitted from contaminants on those items.	
INTERNAL		
Inhalation of resuspended fallout	USS BRUSH crew members who collected souvenirs were exposed to resuspended fallout while on contaminated target ships.	Breathing rate of 2.0 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. GSMF of 4.06 instead of 2.
Ingestion of contaminants on souvenirs	USS BRUSH crew members who collected souvenirs transferred contaminants from souvenir to hands to mouth.	

Table 2. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartOp}$	Date USS BRUSH arrived at Kwajalein Atoll	February 25, 1947 (USS BRUSH, 1947)
$Date_{EndOp}$	Date nominal crewman detached from USS BRUSH	February 27, 1948
EXTERNAL DOSE		
Int_{TS}	Average topside exposure rate of target ships at Kwajalein on date of boarding	0.055 R day^{-1} (Phillips et al., 1985)
T_{Souv}	Time spend in close proximity (within one meter) to souvenirs on day of collection	2 hours
SA_{Table}	Estimated surface area of souvenirs, equated to area of display table	10 m^2
SA_{BD}	Estimated habitable below-deck area of USS BRUSH	500 m^2
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-3)
$Frac_{BD}$	Fraction of time nominal crewman spent below deck on USS BRUSH	16/24 = 0.667
INTERNAL DOSE		
$GSMF$	Maximum gamma source modification factor for target ships at Kwajalein on date of boarding	4.06 (highest value for target ships present; Phillips et al., 1985, and Weitz, 2009)
K	Resuspension factor while on target ships	10^{-5} m^{-1}
BR	Breathing rate while on target ships	2.0 m^3 hr^{-1}
SA_{Hands}	Estimated surface area of both hands (assumed contaminated and ingested)	0.034 m^2
T_{sh}	Souvenir-to-hand transfer factor	0.3 (Weitz, 2011)
T_{hm}	Hand-to-mouth transfer factor	0.5 (Weitz, 2011)
DCF_{InhFBE} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the USS BRUSH Crew are summarized in Table 3. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 3 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 3. External and Internal Doses and Upper Bounds for USS BRUSH Crew

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	0.08		0.3	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.009	0.03	0.09	0.3
Bone Surface	5	0.3	51	3
Brain	0.009	0.02	0.09	0.2
Breast	0.009	0.02	0.09	0.2
Stomach Wall	0.009	0.05	0.1	0.5
Small Intestine Wall	0.01	0.1	0.1	1
Upper Large Intestine Wall	0.01	0.5	0.2	5
Lower Large Intestine Wall	0.02	2	0.2	13
Kidney	0.03	0.03	0.3	0.3
Liver	2	0.06	11	0.6
Extra-Thoracic Region	0.05	0.05	0.5	0.5
Lung	0.1	0.4	1	4
Muscle	0.009	0.02	0.09	0.2
Pancreas	0.009	0.02	0.09	0.3
Red Marrow	0.3	0.08	3	0.8
Spleen	0.009	0.02	0.09	0.2
Testes	0.07	0.02	0.7	0.2
Thymus	0.009	0.02	0.09	0.2
Thyroid	0.009	0.02	0.09	0.2
Urinary Bladder Wall	0.009	0.03	0.09	0.3

* NPE = no potential for exposure.

The upper-bound doses in Table 3 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 4. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 4. Cancers not Recommended for Expedited Processing for USS BRUSH Crew

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Bone	Bone Surfaces	53
Total EPG upper-bound dose below but close to the screening dose		
Bile Duct	Liver	12
Gall Bladder	Liver	12
Liver	Liver	12

6. References

Berkhouse, L., Davis, S. E., Gladeck, F. R., Hallowell, J. H., Jones, C. B., Martin, E. J., McMullan, F. W., and Osborne, M. J., 1984. *Operation CROSSROADS: 1946*. DNA 6032F, Defense Nuclear Agency, Washington, D.C. May 1.

DTRA (Defense Threat Reduction Agency), 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment - Nuclear Test Personnel Review Program, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Phillips, J., Klemm, J., and Goetz, J., 1985. *Internal Dose Assessment – Operation CROSSROADS*. DNA-TR-84-119, Defense Nuclear Agency, Washington, D.C. October 30.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

USS BRUSH, 1947. *Deck Log of USS BRUSH (DD 745)*, February-March.

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1)*. NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R.L., 2011. *Transfer of Deposited Fallout from Surface-to-Hands and from Hands-to-Mouth*. NTPR-TM-11-xx, Defense Threat Reduction Agency, Fort Belvoir, VA.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Bikini Scientific Resurvey Team (July–August, 1947)

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Bikini Scientific Resurvey Team (July–August, 1947)

1. Description of the Expedited Processing Group

The Bikini Scientific Resurvey (July–August, 1947) Expedited Processing Group (EPG) consists of personnel who took part in a resurvey of Bikini Atoll in July and August 1947. While specific activities of the resurvey participants varied, the sources of radiation resulting in exposure were common among team members. Therefore, it is reasonable to include the participants of the 1947 Bikini Resurvey in a single EPG.

Operation CROSSROADS consisted of two 21-kiloton nuclear tests, designated ABLE and BAKER, conducted in 1946 at Bikini Atoll in the Marshall Islands and is described in Berkhouse et al. (1984).

Some 700 personnel participated in the Bikini Scientific Resurvey during July–August, 1947. The list of ships that participated is included in Table 1 (Berkhouse et al., 1984; Hines, 1962).

There are no specific exclusions for this EPG.

Table 1. Participating Ships in Bikini Resurvey

Ship	Function	Size
USS CHILTON (APA 38)	Task Force 10.12 Flagship	550*
USS COUCAL (ARS 8)	Task Force 10.12 Underwater Operations	110
LCI(L) 615	Task Force 10.12 Ship-to-Shore Operations	20
LSM 382	Task Force 10.12 Ship-to-Shore Operations	40
	Total	720

* Includes 38 members of Navy Construction Battalion Detachment 1800.

2. Basis of Dose Analysis for Bikini Scientific Resurvey

To estimate EPG doses for members of the Bikini Scientific Resurvey team, a scenario was developed based on activities of personnel with the highest dose from exposure external residual radiation and corresponding internal doses. These individuals are referred to as the "highest-dose cohort."

For this EPG, the activities of the Navy Construction Battalion Detachment 1800 form the basis for the generic highest-dose cohort scenario (DTRA, 2008, Appendix B-1) for the following reasons:

- This element consists of a distinct group.
- The gamma radiation exposure rates and the concentrations of radioactive materials available for intake via inhalation and ingestion encountered by island-based personnel were greater than those to which ship-based participants were exposed except for the divers assigned to USS COUCAL who could have received higher doses.

As explained below, several dose components and assumptions were added to the documented Bikini Island resident scenario to produce EPG doses. The basic scenario of participation and radiation exposure of the Resurvey Team members stationed on Bikini Island is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: Navy Construction Battalion Detachment 1800

To estimate EPG doses for all military personnel who participated in the 1947 Bikini Scientific Resurvey, a generic high-sided exposure scenario was developed based on activities of the of the Navy Construction Battalion Detachment 1800.

USS CHILTON and USS COUCAL arrived at Bikini Atoll on July 15, 1947, followed by LCI(L) 615 on July 17 and LSM 382 on August 5. Immediately after the receipt of radiological clearance on July 15 to proceed with work on Bikini Island, personnel from USS CHILTON set about offloading equipment and renovating structures. By July 22, barracks, laboratories, a galley, and a beer hall were functioning and Navy Construction Battalion Detachment 1800 established full-time residence on Bikini Island. This contingent remained on the island until August 25, when shore establishments were secured and loading of ships commenced (Berkhouse et al., 1984; AFSWP, 1947).

There was potential for radiation exposure on Bikini Island, the only site of land-based participants during the resurvey. The initial radiological survey found that the exposure rates at that time were 0.004 R day^{-1} on the lagoon-side beach and 0.03 R day^{-1} in algal beds and other scattered locations in the northwestern tip of the island. The year-old radioactive contamination contributed to both the external and internal doses of personnel at those locations. To measure external radiation exposures, Radiological Safety Officers issued film badges daily to individuals entering hazardous areas, and collected the badges at the end of each day for delivery to the Photographic Dosimetry Unit (PDU) for processing. Neither the badges nor listings of readings have been located for any of the Bikini Scientific Resurvey participants. However, it is documented that none of the more than 500 film badges processed by the PDU had a reading in excess of the daily tolerance limit of 0.1 R (0.07 rem) (Berkhouse et al., 1984; AFSWP, 1947).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions are added to an already high-sided Navy Construction Battalion Detachment 1800 cohort analysis:

- It is assumed that the highest-dose cohort worked and was billeted on the northwest tip of the island in the site of the highest measured exposure rate.
- The number of hours spent outside is increased16 hr day^{-1} from the default 14.4 hr day^{-1} (DTRA, 2010, ED02).
- Although personnel spend their time indoors in either a tent or a metal building, it is assumed that they spent 100 percent of this time in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2 (DTRA, 2010, ED02).
- The resuspension factor in the vicinity of the cohort is 2 times larger than the standard value for aged fallout. This enhancement resulted from mechanical disturbances of the soil during construction activities, which are assumed to have continued throughout their stay on the island.
- The breathing rate for outdoor activities is 2.0 m^3 hr^{-1} instead of the standard value of 1.2 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity Weitz et al. (2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for the Bikini Scientific Resurvey Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from contaminants on Bikini Island	Navy Construction Battalion Detachment 1800 personnel were exposed to residual radiation from radioactive debris deposited on Bikini Island by Shot BAKER. Navy Construction Battalion Detachment 1800 personnel worked and billeted at the site of the highest exposure rate measured in the initial resurvey of Bikini Island.	Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1}. Assumed the lowest protection factor of 1.5 for tents while indoors.
INTERNAL		
Inhalation of resuspended fallout	Navy Construction Battalion Detachment 1800 personnel inhaled resuspended Shot BAKER fallout while working outside on Bikini Island. Navy Construction Battalion Detachment 1800 personnel worked and billeted at the site of the highest exposure rate measured in the initial resurvey of Bikini Island.	Cohort spent 16 hr day^{-1} outside instead of 14.4 hr day^{-1}. Resuspension factor was enhanced by a factor of 2 due to mechanical disturbances of the soil induced by construction activity. Assumed a breathing rate of 2.0 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust	Navy Construction Battalion Detachment 1800 personnel incidentally ingested fallout-contaminated soil and dust during construction work on Bikini Island.	.

Table 3. Input Parameters Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Start}$	Date first elements of resurvey team arrived at Bikini Atoll	July 15, 1947 (Berkhouse et al., 1984)
$Date_{End}$	Date last elements of resurvey team departed Bikini Atoll	August 29, 1947 (Berkhouse et al., 1984)
EXTERNAL DOSE		
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
I_{ref}	Highest exposure rate measured during resurvey of Bikini Island	0.03 R day-1 (Berkhouse et al., 1984)
λ_{BI}	Decay exponent for CROSSROADS fallout on Bikini Island	1.23 (Thomas, 1986)
$Frac_{os}$	Fraction of time spent outside on Bikini Island	0.67 (= 16/24)
PF_t	Protection factor while in a tent	1.5 (DTRA, 2010, SM ED02)
INTERNAL DOSE		
$K_{en}(t)$	Resuspension factor on Bikini Island (enhanced by factor of 2)	Ken(t) = 2 × 10−5 × e(-0.01 × t/24) + 10−9 m-1 (DTRA, 2010, SM ID01)
BR	Breathing rate	2.0 m3 hr−1
q_{ing}	Soil ingestion rate	500 mg day−1 (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm−3 (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Bikini Scientific Resurvey Team are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Bikini Scientific Resurvey Team

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	0.8		3	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.009	0.003	0.09	0.02
Bone Surface	5	0.2	49	1
Brain	0.009	0.003	0.09	0.007
Breast	0.009	0.003	0.09	0.01
Stomach Wall	0.009	0.006	0.09	0.02
Small Intestine Wall	0.009	0.01	0.09	0.03
Upper Large Intestine Wall	0.009	0.05	0.09	0.1
Lower Large Intestine Wall	0.01	0.2	0.09	0.3
Kidney	0.02	0.003	0.3	0.01
Liver	1	0.03	11	0.3
Extra-Thoracic Region	0.05	0.02	0.5	0.2
Lung	0.1	0.3	1	3
Muscle	0.009	0.003	0.09	0.008
Pancreas	0.009	0.003	0.09	0.01
Red Marrow	0.3	0.02	3	0.08
Spleen	0.009	0.003	0.09	0.01
Testes	0.07	0.004	0.7	0.02
Thymus	0.009	0.003	0.09	0.02
Thyroid	0.009	0.003	0.09	0.008
Urinary Bladder Wall	0.009	0.003	0.09	0.008

* NPE = no potential for exposure

The upper-bound doses in Table 4were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 5. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. Cancer Cases not Recommended for Expedited Processing for Bikini Scientific Resurvey Team

Organ or Tissue Cancer	NTPR Standard Organs	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Bone	Bone Surface	54
Liver	Liver	15
Total EPG upper-bound dose below but close to the screening dose		
Bile Duct	Liver	15
Gall Bladder	Liver	15

6. References

AFSWP (Armed Forces Special Weapons Project), 1947. *Technical Report (of) Bikini Scientific Resurvey – Operations*. XRD-212, Armed Forces Special Weapons Project, Kirtland Air Force Base, NM. December.

Berkhouse, L., Davis, S. E., Gladeck, F. R., Hallowell, J. H., Jones, C. B., Martin, E. J., McMullan, F. W., and Osborne, M. J., 1984. *Operation CROSSROADS: 1946*. DNA 6032F, Defense Nuclear Agency, Washington, D.C. May 1.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment - Nuclear Test Personnel Review Program. Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Hines, N. O., 1962. Proving Ground – An Account of the Radiobiological Studies in the Pacific, 1946-1961 (University of Washington Press, Seattle, Washington, D.C.).

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11 Defense Threat Reduction Agency, Fort Belvoir, VA).

Thomas, C., 1986. *Radiological Contamination on the Islands of Bikini Atoll at Operations CROSSROADS*. Science Applications International Corporation, McLean, VA.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation SANDSTONE Ship-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation SANDSTONE Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation SANDSTONE Ship-Based Personnel Expedited Processing Group (EPG) consists of approximately 6,400 personnel who were assigned to U.S. Navy and U.S. Army ships during Operation SANDSTONE (1948) (Berkhouse et al., 1983; Thomas et al., 1983a). Although general activities of the crew members of the various ships in this EPG were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure of these participants involving relevant SANDSTONE shots were similar. Therefore it is reasonable to include most participants assigned to ship crews during Operation SANDSTONE in a single EPG.

The SANDSTONE test series comprised three shots that were detonated at Enewetak Atoll in the Pacific Proving Ground (PPG) from April 15 to May 15, 1948. Joint Task Force 7 (JTF 7) was responsible for the conduct of the operation and consisted of elements of all four military services, the Atomic Energy Commission (AEC), and Federal civilian agencies and their contractors. JTF 7 was organized into functional and service branch oriented task groups (TG), although there were cross-service TG assignments. Ship-based personnel were assigned to TG 7.3, and consist primarily of naval personnel but also include members of the other services. The TG 7.3 ships are listed in Table 1 (Berkhouse et al., 1983; DTRA, 2008, Appendix B-2; Thomas et al., 1983a).

The following individuals and cohorts are excluded from expedited processing under this EPG:

- Individuals who boarded Operation CROSSROADS target ships moored at Kwajalein.
- Individuals who participated in Enewetak and Bikini Atoll resurveys during Post-SANDSTONE operations.
- Individuals who participated in a special project known as Operation FITZWILLIAM.

2. Basis of Dose Analysis for SANDSTONE Ship-Based Personnel

To estimate EPG doses for all SANDSTONE ship-based personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose. This cohort is referred to as the "highest-dose cohort." Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

Table 1. Ships Assigned to Task Group 7.3[*] at Operation SANDSTONE

Ship	Task Unit	Size
USS ALBEMARLE (AV-5)	7.3.2 (Main Naval Task Unit)	537
USS AREQUIPA (AF-31)	7.3.5 (Service Unit)	75
USS ASKARI (ARL-30)	7.3.7 (Boat Pool Unit)	164
AVR C-26638, AVR C-26653	7.3.3 (Off-Shore Patrol Unit)	12
USS BAIROKO (CVE-115)	7.3.4 (Helicopter Unit)	770
USS COMSTOCK (LSD-19)	7.3.7 (Boat Pool Unit)	252
USS CURRIER (DE-700)	7.3.3 (Off-Shore Patrol Unit)	136
USS CURTISS (AV 4)	7.3.2 (Main Naval Task Unit)	555
USS DAVISON (DMS-37)	7.3 (Commander, Task Group)	170
USS GARDINERS BAY (AVP-39)	7.3.3 (Off-Shore Patrol Unit)	265
USS GEORGE (DE-697)	7.3.3 (Off-Shore Patrol Unit)	141
USS GULL (AMS-16)	7.3 (Commander, Task Group)	24
USS HENRY W. TUCKER (DDR-875)	7.3.3 (Off-Shore Patrol Unit)	233
LCI(L)-549, LCI(L)-1054, LCI(L)-1090	7.3.7 (Boat Pool Unit)	60
LCT-472, LCT-494, LCT-1194, LCT-1345	7.3.7 (Boat Pool Unit)	[†]
LSM-250, LSM-378	7.3.6 (Cable Unit)	104
USS LST-45, USS LST-219, USS LST-611	7.3.2 (Main Naval Task Unit)	179
USS MARSH (DE-699)	7.3.3 (Off-Shore Patrol Unit)	138
USS MISPILLION (AO-105)	7.3.5 (Service Unit)	173
USS MOUNT MCKINLEY (AGC-7)	7.3.1 (Flagship Unit)	578
USS PASIG (AW-3)	7.3.5 (Service Unit)	164
USS PELICAN (AMS-32)	7.3 (Commander, Task Group)	25
USS PERKINS (DDR-877)	7.3.3 (Off-Shore Patrol Unit)	223
USS PICKAWAY (APA-222)	7.3.2 (Main Naval Task Unit)	290
USS QUICK (DMS-37)	7.3 (Commander, Task Group)	167
USS RABY (DE-698)	7.3.3 (Off-Shore Patrol Unit)	143
USS ROGERS (DDR-876)	7.3.3 (Off-Shore Patrol Unit)	234
USS SPANGLER (DE-696)	7.3.3 (Off-Shore Patrol Unit)	135
USS SWALLOW (AMS-36)	7.3 (Commander, Task Group)	23
USATS FS-211, USATS FS-234, USATS FS-370	7.3 (Commander, Task Group)	52
USS WARRICK (AKA-89)	7.3.2 (Main Naval Task Unit)	167
USS YANCEY (AKA-93)	7.3.2 (Main Naval Task Unit)	148
YOG-64	7.3.5 (Service Unit)	11
YW-94	7.3.5 (Service Unit)	[†]
	Total	6,348

[*] Non-TG 7.3 ships are known to have been in or near the PPG during the operation or during pre- or post-operation time periods. These ships were not assigned to JTF 7 and they were not directly involved in Operation SANDSTONE. However, these ships may have been subject to fallout from SANDSTONE shots. Any doses incurred by crewmembers are bounded by the doses calculated for this EPG, as long as no EPG exclusion conditions are met. These ships include USS ASHTABULA (AO-51), USS ATLANTA (CL-51), USS CHEHALIS (AOG-48), USS CIMARRON (AO-22), USS DULUTH (CL-87), USS HELENA (CA-75), USS KERSTIN (AF-34), USS KLICKITAT (AOG-64), USS LATONA (AF-35), LCI-615, USS NEMASKET (AOG-10), USS OAKLAND (CL-95), USS RYER (AG-138), USS TOLEDO (CA-133) (Thomas et al., 1983a; DTRA 2008, Appendix B-2).

[†] Number of crewmembers is unknown (Berkhouse et al., 1983; Thomas et al., 1983a).

For this EPG, the activities of personnel assigned to USS HENRY W. TUCKER form the basis for the exposure scenario of the highest-dose cohort (Thomas et al., 1983a) for two primary reasons:

- The group received the largest average external gamma dose from residual radiation for all SANDSTONE ship-based personnel.
- The operating history of the group of the ship is well-documented.

As explained below, several dose components and assumptions were added to the documented USS HENRY W. TUCKET scenario (Thomas et al., 1983a) to produce EPG doses. The basic scenario of participation and radiation exposure of the USS HENRY W. TUCKET is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: Crew of USS HENRY W. TUCKER

To estimate EPG doses for all military personnel assigned to residence islands in the PPG or supporting islands during Operation SANDSTONE, a generic high-sided exposure scenario was developed based on activities of crew members of USS HENRY W. TUCKER. This ship was a radar picket destroyer that arrived at Enewetak Atoll on March 18, 1948, where it was one of eight destroyers assigned to the Off-Shore Patrol Unit. These ships supported ship movements to and from Enewetak Atoll and also provided anti-submarine patrols around the atoll while the operation was in progress. At the times of the three SANDSTONE shots, USS HENRY W. TUCKER was on patrol about 15 nautical miles off the shot island. When not on patrol, USS HENRY W. TUCKER remained anchored in the lagoon where it took on fuel, oil, and water in preparation for its next patrol assignment. The crew was presumably allowed shore liberty on Enewetak Island or Parry Island during times that the ship was anchored in the lagoon. USS HENRY W. TUCKER departed from the PPG on May 21, 1948 (Berkhouse et al., 1983; DTRA 2008, Appendix B-2; Thomas et al., 1983a).

USS HENRY W. TUCKER did not receive any primary (early-time) fallout from any SANDSTONE shots; secondary (late-time) fallout is the only fallout experienced by the ship. All three SANDSTONE shots also resulted in fallout at the shore liberty islands of Enewetak Atoll. The three sources of exposure to crewmembers of USS HENRY W. TUCKER were fallout from SANDSTONE shots while on board the ship, residual radiation from the XRAY nuclear cloud, and fallout on liberty islands. Average fallout exposure rates measured on the Enewetak Island are applicable to USS HENRY W. TUCKER and other ships anchored in the vicinity. The three SANDSTONE shots and the resulting fallout exposure rates for USS HENRY W. TUCKER are shown in Table 2 (note that there were two episodes of Shot XRAY fallout). The time-dependent fallout exposure rates on USS HENRY W. TUCKER due to fallout from the three SANDSTONE shots are shown in Figure 1 , Figure 2, and Figure 3 (DTRA, 2008, Appendix B-2).

Table 2. Operation SANDSTONE Shots and Resulting Fallout Exposure Rates on USS HENRY W. TUCKER

Shot	Shot Date (1948) and Time	Peak Exposure Rate (R hr^{-1})	Peak Time (H+hr)
XRAY	April 15 at 0617	0.00023 0.0001	14 48
YOKE	May 1 at 0609	0.0003	54
ZEBRA	May 15 at 0604	0.00004	144

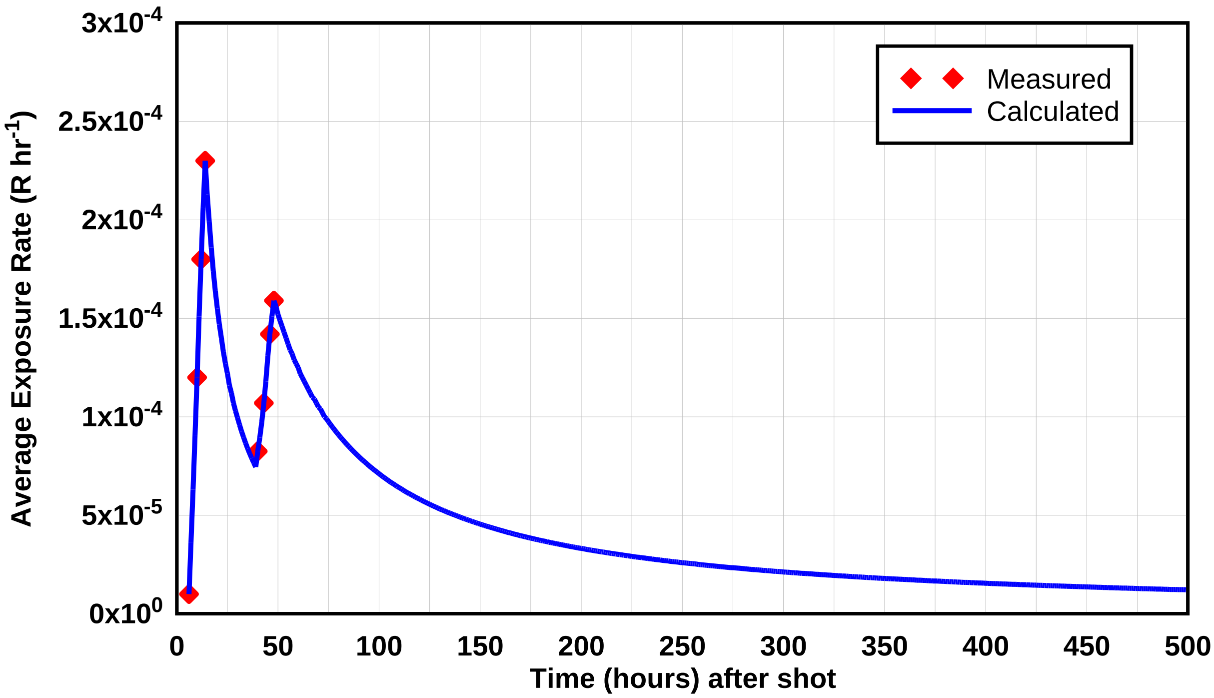

Figure 1. Average Topside Residual Exposure Rate on USS HENRY W. TUCKER from Shot XRAY

Figure 2. Average Topside Residual Exposure Rate on USS HENRY W. TUCKER from Shot YOKE

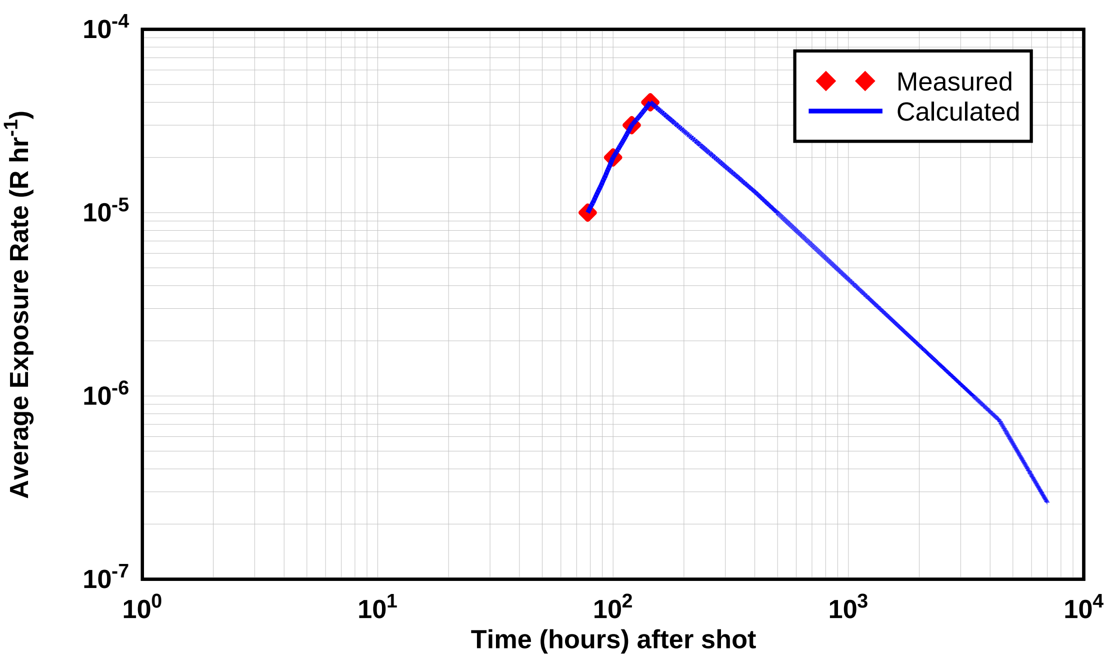

Figure 3. Average Topside Residual Exposure Rate on USS HENRY W. TUCKER from Shot ZEBRA

Based on these intensities, decayed to the end of the operation and then one year beyond, the crew of USS HENRY W. TUCKER accrued external doses from deposited fallout while topside and below deck while on board. The crew also accrued an external dose from the XRAY nuclear cloud that passed over USS HENRY W. TUCKER shortly after the XRAY detonation. The final source of external dose to crew members was from deposited fallout at the liberty islands. The crew of USS HENRY W. TUCKER received internal doses from resuspended fallout during their time topside while on board ship, during their time out of doors while on shore liberty and from incidental ingestion of contaminated soil and dust during shore liberty (DTRA, 2008, Appendix B-2).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions, as described below, were added to the highest-dose cohort analysis:

- The period of assignment is from prior to the first fallout event until May 31, 1949. This end date corresponds to one year after the end of Operation SANDSTONE.
- The number of hours spent topside is increased from 14.4 to 16 hr day^{-1}, while 8 hours per day were spent below deck for sleeping, cleaning and eating.
- A ship shielding factor of 0.15 (fraction transmitted to below-deck spaces) was used instead of the inferred average value of 0.117 (DTRA, 2008, Appendix B-2).
- Crewmembers are assumed to be topside during the passage of the XRAY nuclear cloud and were fully exposed to external residual radiation from the cloud.
- Periodic closures of the shore liberty recreational facilities are ignored, and personnel are assumed to have used shore recreational facilities an average of 4 hours every four days throughout the period April 15–May 31, 1948 (DTRA, 2008, Appendix B-2).
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure pathways for the Operation SANDSTONE Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from deposited fallout while topside during and after Operation SANDSTONE	USS HENRY W. TUCKER crew members were exposed to residual radiation due to fallout from Shots XRAY, YOKE, and ZEBRA while topside during the operational period.	Time topside is 16 hr day^{-1} instead of 9.6 hr day^{-1}.
Residual radiation from deposited fallout while below deck during and after Operation SANDSTONE	USS HENRY W. TUCKER crew members were exposed to residual radiation due to fallout from Shots XRAY, YOKE, and ZEBRA while below deck during the operational period.	Shielding factor (fraction transmitted) is 0.15 instead of 0.117.
External gamma dose from cloud shine	USS HENRY W. TUCKER crew members were exposed to cloud shine from the passing XRAY nuclear cloud shortly after Shot XRAY.	
Residual radiation from deposited fallout while on shore liberty during Operation SANDSTONE	USS HENRY W. TUCKER crew members were exposed to residual radiation due to fallout from Shots XRAY, YOKE, and ZEBRA at Enewetak Atoll during shore liberty.	Shore recreational facilities are available the entire operational period for 4 hours every 4 days.
INTERNAL		
Inhalation of resuspended fallout from three fallout episodes while topside	USS HENRY W. TUCKER crew members inhaled resuspended fallout from Shots XRAY, YOKE, and ZEBRA until 100 hours after the time of peak fallout.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during shore liberty periods	USS HENRY W. TUCKER crew members inhaled resuspended fallout from Shots XRAY, YOKE, and ZEBRA during shore liberty periods at Enewetak Atoll.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Shore recreational facilities are available the entire operational period For 4 hours every 4 days. .
Incidental ingestion of contaminated soil/dust from three fallout episodes	USS HENRY W. TUCKER crew members ingested soil and dust at Enewetak Atoll contaminated with fallout from Shots XRAY, YOKE, and ZEBRA during shore liberty.	Shore recreational facilities are available the entire operational period For 4 hours every 4 days.

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartOp}$	SANDSTONE start date[time]	15 Apr 1948[0617]
$Date_{EndOp}$	SANDSTONE end date[time]	31 May 1948[2400]
$Date_{Departed}$	Enewetak Atoll departure date[time]	31 May 1949[2400]
EXTERNAL DOSE		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
SF	Shielding factor while below deck	0.15 (Thomas, 1983b)
$IpeakDet_{XR1}$ $TpeakDet_{XR1}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot XRAY (first episode) aboard ship and at Enewetak Atoll	0.00023 R hr^{-1} at H+14 (DTRA, 2008, Appendix B-2)
$IpeakDet_{XR2}$ $TpeakDet_{XR2}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot XRAY (second episode) aboard ship and at Enewetak	0.00010 R hr^{-1} at H+48 (DTRA, 2008, Appendix B-2)
$IpeakDet_{YK}$ $TpeakDet_{YK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot YOKE aboard ship and at Enewetak Atoll	0.0003 R hr^{-1} at H+54 (DTRA, 2008, Appendix B-2)
$IpeakDet_{ZB}$ $TpeakDet_{ZB}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZEBRA aboard ship and at Enewetak Atoll	0.00004 R hr^{-1} at H+144 (DTRA, 2008, Appendix B-2)
λ_{OpXR}	Decay exponent Shot XRAY fallout during the operational period	1.1 (DTRA, 2008, Appendix B-2)
λ_{OpYK}	Decay exponent Shot YOKE fallout during the operational period	1.0 (DTRA, 2008, Appendix B-2)
λ_{OpZB}	Decay exponent Shot ZEBRA fallout during the operational period	1.1 (DTRA, 2008, Appendix B-2)
λ_{PostXR}	Decay exponent Shot XRAY fallout during the post-operational period	1.2 (DTRA, 2008, Appendix B-2)
λ_{PostYK}	Decay exponent Shot YOKE fallout during the post-operational period	1.0 (DTRA, 2008, Appendix B-2)
λ_{PostZB}	Decay exponent Shot ZEBRA fallout during the post-operational period	1.2 (DTRA, 2008, Appendix B-2)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-2)
$DoseDet_{Shine}$	External dose from passing Shot XRAY nuclear cloud	0.020 rem (= 0.7 rem R^{-1} × 0.02 R hr^{-1} × 1.667 hr) (Thomas et al., 1983a)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$GSMF$	Gamma source modification factor for location of exposure rate measurement	1.0

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
F_{ts}	Fraction of time spent topside (time exposed to resuspended fallout)	0.67 (= 16/24)
$Frac_{SL}$	Fraction of time spent on shore liberty	0.0417 [4 hr every 4th day = 4/(24 × 4)]
K_{Ship}	Resuspension factor for resuspension of fallout from ship surfaces	$K = 10^{-5}$ (DTRA, 2010, SM ID01)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate during shore liberty periods	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density during shore liberty periods	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{inhACT} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 μm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-REDWING ship-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for Operation SANDSTONE Ship-Based Personnel

External Doses	EPG Dose (rem)		EPG Dose (rem)	
Residual Gamma Radiation	0.09		0.3	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	<0.001	<0.001	<0.001
Bone Surface	<0.001	<0.001	0.004	0.002
Brain	<0.001	<0.001	<0.001	<0.001
Breast	<0.001	<0.001	<0.001	<0.001
Stomach Wall	<0.001	<0.001	<0.001	<0.001
Small Intestine Wall	<0.001	<0.001	<0.001	0.002
Upper Large Intestine Wall	<0.001	<0.001	<0.001	0.006
Lower Large Intestine Wall	<0.001	0.002	<0.001	0.02
Kidney	<0.001	<0.001	<0.001	<0.001
Liver	<0.001	<0.001	<0.001	<0.001
Extra-Thoracic Region	<0.001	0.002	<0.001	0.02
Lung	<0.001	0.003	<0.001	0.03
Muscle	<0.001	<0.001	<0.001	<0.001
Pancreas	<0.001	<0.001	<0.001	<0.001
Red Marrow	<0.001	<0.001	<0.001	<0.001
Spleen	<0.001	<0.001	<0.001	<0.001
Testes	<0.001	<0.001	<0.001	<0.001
Thymus	<0.001	<0.001	<0.001	<0.001
Thyroid	<0.001	0.003	<0.001	0.03
Urinary Bladder Wall	<0.001	<0.001	<0.001	<0.001

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010,SM ED02).

6. References

Berkhouse, L.H., Hallowell, J.H., McMullan, F.W., Davis, S.E., Jones, C.B., Osborn, M.J., Gladeck, F.R., Martin, E.J., and Rogers, W.E., 1983. *Operation SANDSTONE: 1948.* DNA 6033F. Defense Nuclear Agency, Washington, DC. December 19.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01. Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11. Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J., Stuart, J., and Klemm, J., 1983a. *Analysis of Radiation Exposure for Naval Personnel at Operation SANDSTONE*. DNA-TR-83-13. Defense Nuclear Agency, Washington, DC. August 15.

Thomas, C., Goetz, J., Stuart, J., and Klemm, J., 1983b. *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*. DNA-TR-82-98. Defense Nuclear Agency, Washington, DC. March 15.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13. Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1)*. NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation SANDSTONE Land-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group:
Operation SANDSTONE Land-Based Personnel

1. Description of the Expedited Processing Group

The Operation SANDSTONE Land-Based Personnel Expedited Processing Group (EPG) consists of approximately 5,000 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak and Parry Islands) and Kwajalein Atoll (Kwajalein Island) during any period during Operation SANDSTONE.

The SANDSTONE test series comprised three shots that were detonated at Enewetak Atoll in the Pacific Proving Ground (PPG) from April 15 to May 15, 1948. All three shots resulted in fallout at Enewetak, Parry, and Kwajalein Islands. Joint Task Force 7 (JTF 7) was responsible for the conduct of the operation and consisted of elements of all four military services, the Atomic Energy Commission (AEC), and Federal civilian agencies and their contractors. JTF 7 was organized into functional and service branch oriented task groups (TG), although there were cross-service TG assignments. Land-based personnel were assigned to all TGs. Approximately 1,700 Army, 1,200 Navy, 2,000 Air Force, and 150 Marines Corps personnel are included in this EPG, as shown in Table 1. Although general activities of the personnel in this EPG were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure of these participants involving SANDSTONE shots were similar. Therefore it is reasonable to include most participants assigned to one of the residence islands at Enewetak or Kwajalein Atoll during Operation SANDSTONE into a single EPG (Berkhouse et al., 1983; DTRA, 2008, Appendix B-2).

The following individuals and cohorts are excluded from expedited processing under this EPG:

- Individuals who boarded Operation CROSSROADS target ships moored at Kwajalein.
- Individuals who participated in a special project known as Operation FITZWILLIAM that involved laboratory measurements of radioactive samples.
- Individuals who participated in the Bikini and Enewetak Atoll resurveys (Post-SANDSTONE).
- Individuals who were stationed at Majuro Atoll, Rongerik Atoll, or Wake Island.

Table 1. Units and Land-Based Military Personnel Assigned to JTF 7 Task Groups at Operation SANDSTONE

Task Group	Units*	Size†
TG 7.1 (AEC Proving Ground Group)	Army: 38th Engineer Battalion	98
	Air Force: Unit Not Identified (UNI)	2
TG 7.2 (Army)	Army: 1220th Provisional Engineer Battalion 532nd Engineer Boat & Shore Regiment 461st Transportation Amphibious Truck Company 854th Transportation Port Company	1,422
	Navy: Enewetak Shore Detachment; Signal Unit 1	123
TG 7.3 (Navy)	Navy: Air Development Squadron 4 (VX-4) Detachment	54
TG 7.4 (Air Force)	Army: UNI	40
	Navy: Photographic personnel	5
	Air Force: 1st Experimental Guided Missiles Group 311th Air Division 514th Weather Reconnaissance Squadron 5th Air Rescue Squadron 71st Airways and Air Communications Services Group 1535th Air Force Base Unit	1,648
	Marines: UNI	1
TG 7.5 (Joint Security Group)	Army: 369th Counter Intelligence Corps (CIC) Detachment 401st CIC Detachment 8456th Military Police	136
	Air Force: UNI	15
	Marines: UNI	51
TG 7.6 (Joint Rad-Safe Group)	Army: UNI	35
	Air Force: UNI	103
	Marines: UNI	2
TG 7.7 (Kwajalein Island Command)	Navy: Amphibious Patrol Squadron 2 (VPAM-2) Detachment Civil Administration Unit Construction Battalion 1509 Detachment Heavy Lift Patrol Squadron 8 (VPHL-8) Detachment Naval Air Station, Kwajalein Naval Station, Kwajalein Naval Station, Kwajalein, In-Service Craft Naval Station, Kwajalein, Ship Security Detachment Transport Squadron 8 (VR-8) Detachment Utility Transport Squadron 3 (VRU-3) Detachment	971
	Air Force: 2307th Aviation Engineer Company 2308th Aviation Engineer Company 1535th Air Force Base Unit 31-8 Air Weather Service Detachment	213
	Marines: UNI	89
	Total	5,008

* This listing is not complete due to lack of documentation on contributing units.

† Actual levels varied throughout the Operation; these are approximate numbers (Berkhouse et al., 1983).

2. Basis of Dose Analysis for SANDSTONE Land-Based Personnel

To estimate EPG doses for all SANDSTONE land-based personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort." Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, TG 7.3 personnel assigned to Kwajalein Island for the basis for the generic highest-dose cohort (DTRA, 2008 Appendix B-2; Thomas et al., 1983) for two primary reasons:

- Members of TG 7.3 were stationed at Kwajalein for the entire duration of the operation.
- Member of TG 7.3 had no involvement in unique exposure activites.
- The available film badge dosimetry for TG 7.3 supports the reconstructed dose assigned to them.

As explained below, several dose components and assumptions were added to the TG 7.3 scenario (Thomas et al., 1983) to produce EPG doses. The basic scenario of participation and radiation exposure of the Kwajalein Island scenario is described directly below followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Task Group 7.3 Personnel at Kwajalein Island

To estimate EPG doses for all military personnel assigned to residence islands in the PPG or supporting islands during Operation SANDSTONE, a generic high-sided exposure scenario was developed based on activities of TG 7.3 personnel based at Kwajalein Island. TG 7.3 personnel on Kwajalein Island were composed of approximately 54 Navy personnel in the Air Development Squadron Detachment assigned to the Off Shore Patrol Task Unit (7.3.3). All members of the land-based personnel in this unit lived and were assigned duty at Kwajalein Island, where they piloted and maintained three patrol aircraft used to fly nightly patrols. This unit was assigned to Kwajalein Island for the entire period of Operation SANDSTONE (Berkhouse et al., 1983; DTRA 2008, Appendix B-2).

Personnel in the TG 7.3 Kwajalein Island lived on Kwajalein Island and had no involvement in unique exposure activities, so their only source of exposure was fallout from SANDSTONE shots while conducting routine island resident activities on Kwajalein Island. The three SANDSTONE shots and the resulting fallout exposure rates at Kwajalein Island are shown in Table 2. Figures 1–3 show the time-dependent exposure rates on Kwajalein Island due to each fallout event. Based on these exposure rates, decayed to the end of the operation and then one year beyond, TG 7.3 Kwajalein Island personnel accrued external doses from fallout deposited on Kwajalein Island while outside and while indoors. TG 7.3 Kwajalein Island personnel also received internal doses while outdoors during the same period from inhalation of descending fallout, inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust. (DTRA, 2008, Appendix B-2)

Table 2. Operation SANDSTONE Shots and Resulting Fallout Exposure Rates at Kwajalein

Shot	Shot Date (1948) and Time	Peak Exposure rate (R hr^{-1})	Peak Time (H+hr)
XRAY	April 15 at 0617	0.00007	150
YOKE	May 1 at 0609	0.0005	42
ZEBRA	May 15 at 0604	0.00003	306

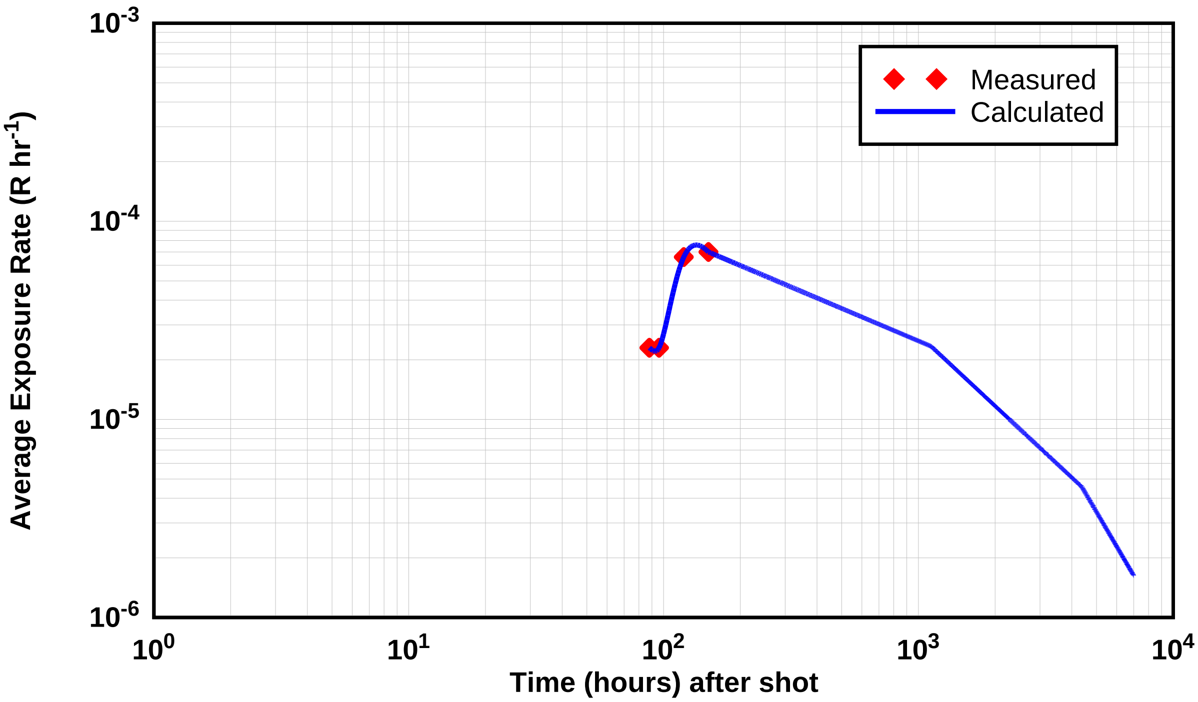

Figure 1. Average Residual Radiation Exposure Rate at Kwajalein Island from Shot XRAY

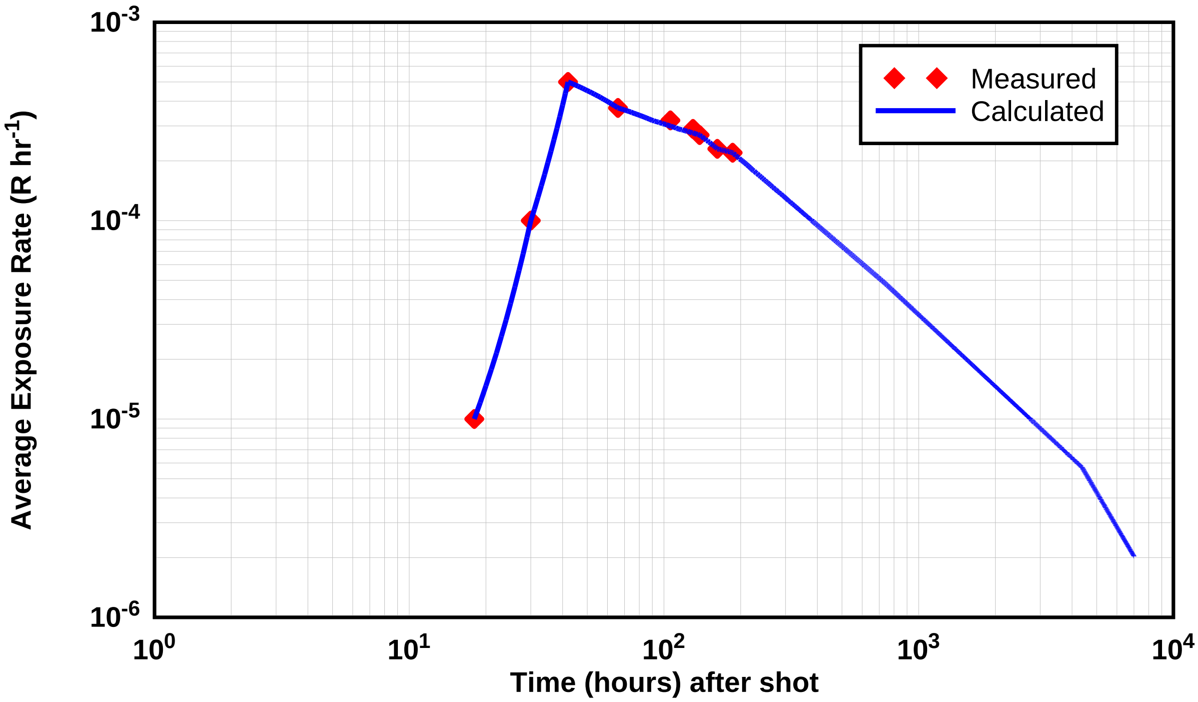

Figure 2. Average Residual Radiation Exposure Rate at Kwajalein Island from Shot YOKE

Figure 3. Average Residual Radiation Exposure Rate at Kwajalein Island from Shot ZEBRA

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions, as described below, were added to the TG 7.3 Kwajalein Island personnel analysis:

- The period of assignment to Kwajalein Island is assumed to be from April 15, 1948 to May 31, 1949. This start date is the date of the first SANDSTONE shot. The end date corresponds to one year after the end of Operation SANDSTONE.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption that personnel activities consisted of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.
- Personnel were assumed to be outdoors during the entire times of descending XRAY, YOKE, and ZEBRA fallout.

Exposure pathways for the EPG scenario are described in Table 3. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure pathways for Operation SANDSTONE Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from three shots during Operation SANDSTONE	TG 7.3 Kwajalein Island personnel were exposed to residual radiation due to fallout from Shots XRAY, YOKE, and ZEBRA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Departure is one year following the end of Operation SANDSTONE instead of actual departure date. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of descending fallout from three fallout episodes	TG 7.3 Kwajalein Island personnel were subjected to descending fallout from Shots XRAY, YOKE, and ZEBRA.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout from three fallout episodes	TG 7.3 Kwajalein Island personnel were subjected to inhalation of resuspended fallout from Shots XRAY, YOKE, and ZEBRA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Departure is one year following the end of Operation SANDSTONE instead of actual departure date. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from three fallout episodes	TG 7.3 Kwajalein Island personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots XRAY, YOKE, and ZEBRA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Departure is one year following the end of Operation SANDSTONE instead of actual departure date.

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartOp}$	SANDSTONE start date[time]	15 Apr 1948[0617]
$Date_{EndOp}$	SANDSTONE end date[time]	31 May 1948[2400]
$Date_{Departed}$	Kwajalein departure date[time]	31 May 1949[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Kwajalein Island	0.67 (= 16/24)
F_{FB}	Film-Badge Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
PF_t	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
$IpeakDet_{XR}$ $TpeakDet_{XR}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot XRAY	0.00007 R hr^{-1} at H+150 (DTRA, 2008, Appendix B-2)
$IpeakDet_{YK}$ $TpeakDet_{YK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot YOKE	0.0005 R hr^{-1} at H+42 (DTRA, 2008, Appendix B-2)
$IpeakDet_{ZB}$ $TpeakDet_{ZB}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZEBRA	0.00003 R hr^{-1} at H+306 (DTRA, 2008, Appendix B-2)
λ_{OpXR}	Decay expoenent for Shot XRAY	0.545 (DTRA, 2008, Appendix B-2)
λ_{OpYK}	Decay expoenent for Shot YOKE	1.1 (DTRA, 2008, Appendix B-2)
λ_{OpZB}	Decay expoenent for Shot ZEBRA	1.1 (DTRA, 2008, Appendix B-2)
λ_{postop}	Decay exponent for post-operation	1.2 (DTRA, 2008, Appendix B-2)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-2)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{InhAct} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 μm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the SANDSTONE land-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for Operation SANDSTONE Land-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	0.2		0.6	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.001	<0.001	0.007
Bone Surface	0.05	0.007	0.5	0.07
Brain	<0.001	<0.001	<0.001	0.003
Breast	<0.001	0.001	<0.001	0.006
Stomach Wall	<0.001	0.002	<0.001	0.02
Small Intestine Wall	<0.001	0.004	<0.001	0.03
Upper Large Intestine Wall	<0.001	0.02	<0.001	0.2
Lower Large Intestine Wall	<0.001	0.03	<0.001	0.3
Kidney	<0.001	0.001	0.002	0.005
Liver	0.01	0.002	0.1	0.02
Extra-Thoracic Region	0.001	0.04	0.005	0.4
Lung	0.001	0.08	0.01	0.8
Muscle	<0.001	0.001	<0.001	0.005
Pancreas	<0.001	0.001	0.002	0.006
Red Marrow	0.002	0.003	0.03	0.03
Spleen	0.001	0.001	0.003	0.005
Testes	<0.001	<0.001	0.006	0.003
Thymus	<0.001	0.001	<0.001	0.007
Thyroid	<0.001	0.06	0.002	0.6
Urinary Bladder Wall	<0.001	0.001	<0.001	0.01

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

6. References

Berkhouse, L.H., Hallowell, J.H., McMullan, F.W., Davis, S.E., Jones, C.B., Osborn, M.J., Gladeck, F.R., Martin, E.J., and Rogers, W.E., 1983. *Operation SANDSTONE: 1948.* DNA 6033F, Defense Nuclear Agency, Washington, DC. December 19.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J., Stuart, J., and Klemm, J., 1983. *Analysis of Radiation Exposure for Naval Personnel at Operation SANDSTONE*. DNA-TR-83-13, Defense Nuclear Agency, Washington, DC. August 15.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation GREENHOUSE Ship-Based Personnel

November 2011

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Expedited Processing Group: Operation GREENHOUSE Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation GREENHOUSE Ship-Based Personnel Expedited Processing Group (EPG) consists of the crews of ships present at the Pacific Proving Ground (PPG) during and after the operation, as listed in Table 1 and Table 2 below (Thomas et al., 1982; Berkhouse et al., 1983).

Operation GREENHOUSE was a test series in which four nuclear devices were detonated at Enewetak Atoll in the PPG in the spring of 1951. Joint Task Force 3 (JTF 3) was responsible for the conduct of the operation. Approximately 3000 Navy personnel were assigned to JTF 3, most of who served aboard ships in the Enewetak area. The Navy operated the ten ships identified in Table 1 in the PPG in support of GREENHOUSE, the first seven (and about 60 small craft) during the operation and the last three during the post-operational period. The transient ships listed in Table 2 are known to have been in or near the PPG during the operation or during post-operational time periods. These ships were not assigned to JTF 3 and were not directly involved in Operation GREENHOUSE. However, these ships may have been subject to fallout from GREENHOUSE shots. Any doses incurred by crewmembers are bounded by the doses calculated for this EPG, provided no EPG exclusion conditions are met (Berkhouse et al., 1983). There are no specific exclusions for this EPG.

Table 1. Operation GREENHOUSE Support Ship-Based Personnel

Ship	Designation	Mission(s)	Size
USS CABILDO	LSD 16	Boat pool	306
USS CURTISS	AV 4	Flag ship; convoy & escort	638
LST 859	LST 859	Transport of scientific personnel	113
USNS SGT. CHARLES E. MOWER	TAP 186	General transport duties	29
USS SPROSTON	DDE 577	Surface patrol; convoy & escort	283
USS WALKER	DDE 517	Surface patrol; convoy & escort	317
USNS LT. ROBERT CRAIG	TAK 252	General transport duties	12
USS CATAMOUNT†	LSD 17	Landing craft retrieval	~240
USNS FRED C. AINSWORTH†	TAP 181	Cargo transportation	~200
USS RIO GRANDE†	AOG 3	Transport of petroleum supplies	~130
		Support Ship Total	~2,300

† Participated only during post-operational period.

Table 2. Operation GREENHOUSE Transient Ship-Based Personnel

Ship	Designation	Size†
USNS BALD EAGLE	T-AF-50	50
USS NEMASKET	AOG-10	130
USCGC PLANETREE	WAGL-307	40
USS PC- 1546	PC-533 Class Submarine Chaser	65
USS CIMARRON	AO-22	300
USNS PVT. F.J. PETRARCA	T-AK-250	80
USS FARIBAULT	AK-179	80
USS PICTOR	AF-54	290
USNS PVT. JOE E. MANN	T-AK-253	100
USNS GENERAL D.E. AULTMAM	T-AP-156	350
USNS GENERAL DANIEL SULTAN	T-AP-120	350
USNS SGT. TRUMAN KIMBRO	T-AK-254	50
USS SUSSEX	AK-213	80
USNS LT ROBERT CRAIG	T-AK-252	100
USS ZELIMA	AF-49	290
	Transient Ship Total	~2,355

† All crew sizes are approximate.

2. Basis of Dose Analysis for Operation GREENHOUSE Ship-Based Personnel

To estimate EPG doses for all GREENHOUSE ship-based personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose. This cohort is referred to as the "highest-dose cohort." For this EPG, personnel assigned to the USNS SGT. CHARLES E. MOWER form the basis for the exposure scenario of the highest-dose cohort.

This scenario forms an adequate basis of the generic highest-dose cohort scenario for this EPG for two primary reasons:

- Personnel assigned to USNS MOWER received the largest average external gamma dose from residual radiation for all GREENHOUSE ship-based personnel (Thomas et al., 1982).
- The operating history of the ship is well-documented (Thomas et al., 1982).

As explained below, several dose components and assumptions were added to the documented USNS MOWER scenario to produce EPG doses. The basic scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Crew of USNS MOWER

To estimate EPG doses for all military personnel assigned to ships that operated in the PPG during and shortly after GREENHOUSE, a generic high-sided exposure scenario was developed based on activities of crew members of USNS MOWER. This ship was present at the PPG for all four GREENHOUSE shots (DTRA, 2008, Appendix B-3). The peak exposure rates and time of peak exposure for all fallout episodes that occurred on USNS MOWER are listed in Table 3 and shown in Figure 1-Figure 3. This ship was equipped with a wash down system for use during periods of fallout. (Thomas et al., 1982; DTRA, 2008, Appendix B-3) Employment of the washdown system prevented the exposure rates aboard USNS MOWER from reaching levels greater than those listed in Table 3.

Table 3. Operation GREENHOUSE Fallout Exposure Rates on USNS MOWER

Shot	Peak Exposure Rate ($R\ hr^{-1}$)	Peak Exposure Rate Time (H+hr)
DOG	0.0384	3.1
EASY	0.0010	24
ITEM	0.0586	11.1

The USNS MOWER also accumulated external doses during shore liberty.

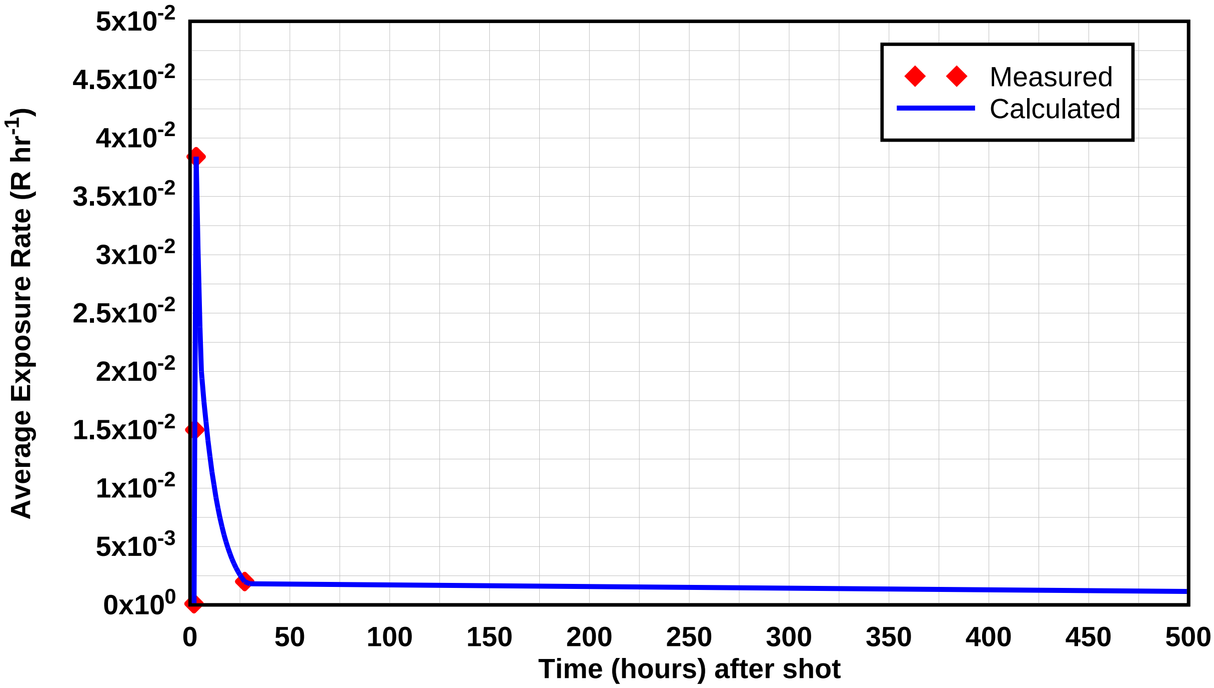

Figure 1. Average Topside Residual Radiation Exposure Rate on USNS MOWER from Shot DOG

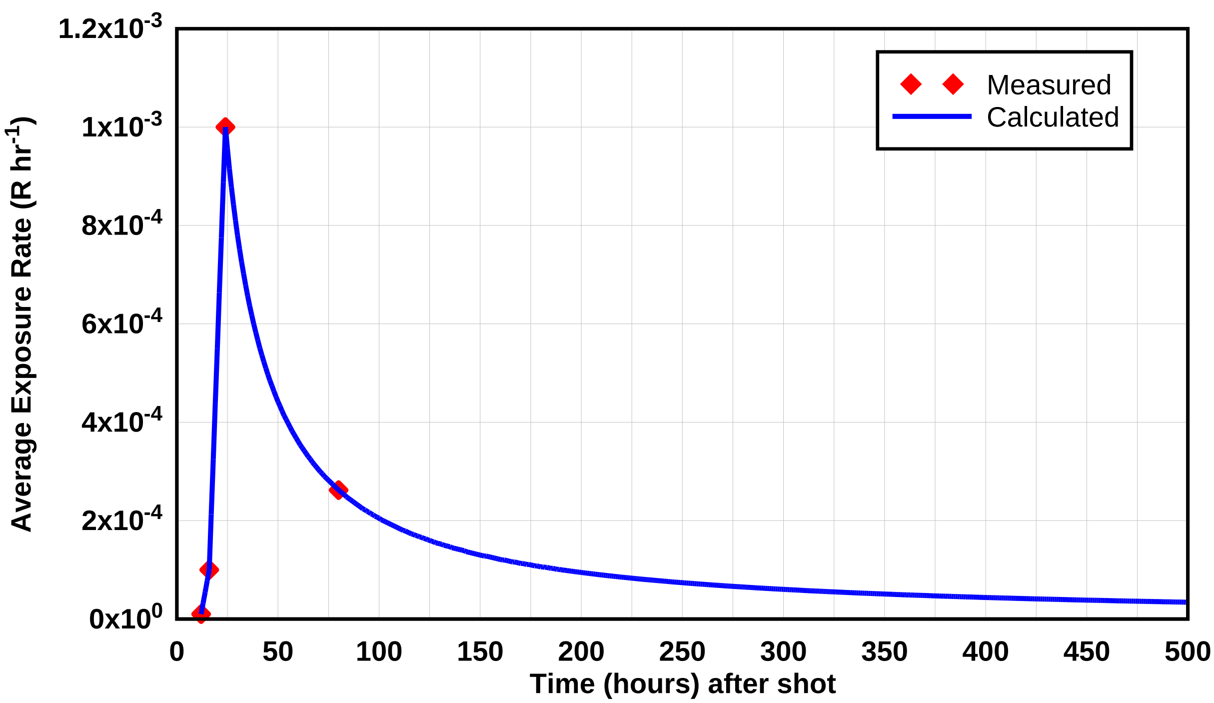

Figure 2. Average Topside Residual Radiation Exposure Rate on USNS MOWER from Shot EASY

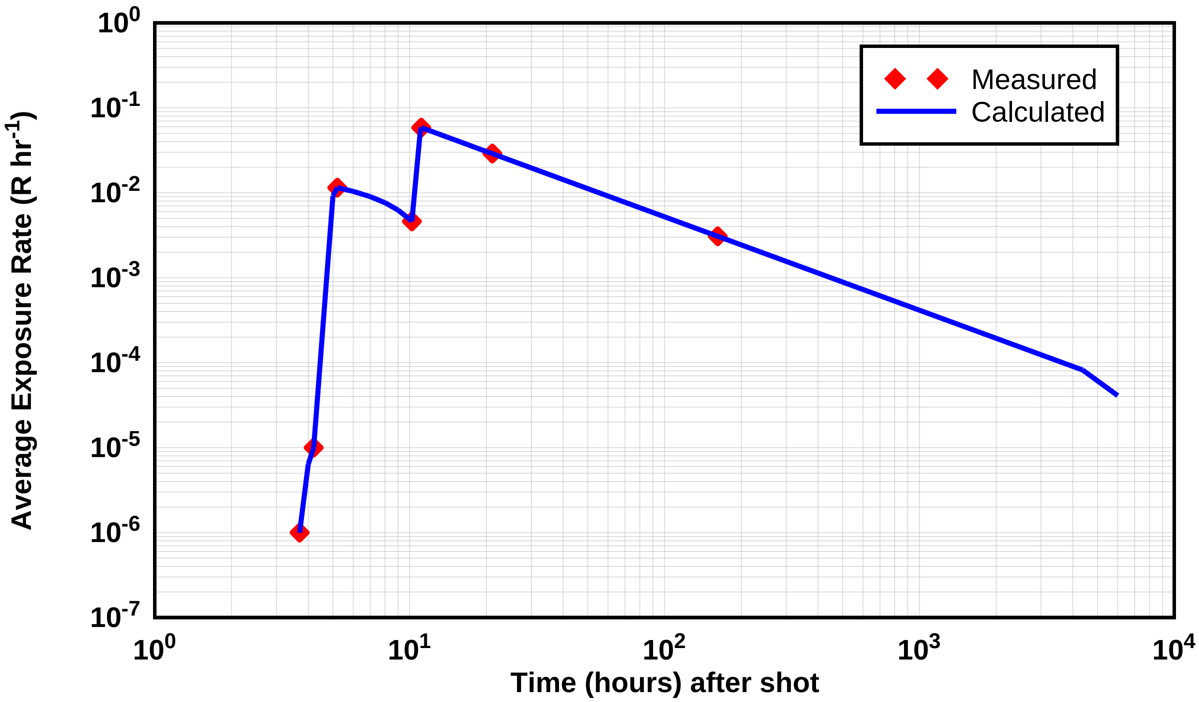

Figure 3. Average Topside Residual Radiation Exposure Rate on USNS MOWER from Shot ITEM

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the generic high-sided analysis:

- The average time spent topside is increased from the default value of 9.6 hr day^{-1} (40 percent of 24 hours) to 16 hr day^{-1}.
- The average shielding factor for below-deck locations (i.e., the ratio of below-deck exposure rate to topside rate) is 0.15, instead of the nominal value 0.10.
- The breathing rate of the cohort is 2.0 m^3 hr^{-1} for all activities instead of the standard value of 1.2 m^3 hr^{-1}. This enhances the amount of resuspended fallout inhaled. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average breathing rate.

Exposure pathways for the EPG scenario are described in Table 4. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 5.

Table 4. Exposure Pathways for GREENHOUSE Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway (High-Dose Scenario)	Maximizing Factors
EXTERNAL		
Residual radiation from fallout deposited topside during and after Operation GREENHOUSE	Crewmembers of USNS MOWER were exposed to fallout from Shots DOG, EASY, and ITEM while topside and below deck during the operational period and for one year following the end of Operation GREENHOUSE.	Time topside is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Used high-sided below-deck ship shielding factor (transmission factor) of 0.15 instead of 0.10.
Residual radiation from deposited fallout while on shore liberty during Operation GREENHOUSE	Crewmembers of USNS MOWER were exposed to fallout from Shots DOG, EASY, and ITEM during shore liberty periods at Enewetak Atoll.	Assumed shore recreational facilities were available the entire operational period of GREENHOUSE
INTERNAL		
Inhalation of resuspended fallout while topside on ship	Crewmembers of USNS MOWER were exposed to resuspended fallout from Shots DOG, EASY, and ITEM.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during shore liberty periods	Crewmembers of USNS MOWER were exposed to resuspended fallout from Shots DOG, EASY, and ITEM during shore liberty periods at Enewetak Atoll.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust during shore liberty periods	Crewmembers of USNS MOWER incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots DOG, EASY, and ITEM during shore liberty periods at Enewetak Atoll.	Assumed shore liberty for four hours every four days.

Table 5. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartOp}$	GREENHOUSE start date[time]	8 Apr 1951[0634]
$Date_{EndOp}$	GREENHOUSE end date[time]	31 May 1951[2400]
$Date_{Detached}$	Ship detached date[time]	31 May 1952[2400]
EXTERNAL DOSE		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
SF	Protection factor while below deck	0.15 (Thomas, et al., 1983)
$IpeakDet_{DG}$ $TpeakDet_{DG}$	Peak topside exposure rate and time of peak exposure rate due to fallout from Shot DOG aboard ship	0.0384 R hr^{-1} at H+3.1 (DTRA, 2008, Appendix B-3)
$IpeakDet_{ES}$ $TpeakDet_{ES}$	Peak topside exposure rate and time of peak exposure rate due to fallout from Shot EASY aboard ship	0.001 R hr^{-1} at H+24 (DTRA, 2008, Appendix B-3)
$IpeakDet_{IT}$ $TpeakDet_{IT}$	Peak topside exposure rate and time of peak exposure rate due to fallout from Shot ITEM aboard ship	0.0586 R hr^{-1} at H+11 (DTRA, 2008, Appendix B-3)
$IpeakDet_{DGEnew}$ $TpeakDet_{DGEnew}$	Peak topside exposure rate and time of peak exposure rate due to fallout from Shot DOG during shore liberty	0.083 R hr^{-1} at H+6 (DTRA, 2008, Appendix B-3)
$IpeakDet_{ESENew}$ $TpeakDet_{ESEnew}$	Peak topside exposure rate and time of peak exposure rate due to fallout from Shot EASY during shore liberty	0.001 R hr^{-1} at H+24 (DTRA, 2008, Appendix B-3)
$IpeakDet_{ITENew}$ $TpeakDet_{ITEnew}$	Peak topside exposure rate and time of peak exposure rate due to fallout from Shot ITEM during shore liberty	0.118 R hr^{-1} at H+14 (DTRA, 2008, Appendix B-3)
λ_{DG}	Decay exponent for times less than H+ 4380 for Shot DOG	1.083 (DTRA, 2008, Appendix B-3)
λ_{ES}	Decay exponent for times less than H+ 4380 for Shot EASY	1.1 (DTRA, 2008, Appendix B-3)
λ_{IT}	Decay exponent for times less than H+ 4380 for Shot ITEM	1.1 (DTRA, 2008, Appendix B-3)
λ_{postop}	Decay exponent for times less than H+ 4380 for post operation periods	1.2 (DTRA, 2008, Appendix B-3)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-3)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for all activities	2.0 m^3 hr^{-1}
$GSMF_{TAP}$	Gamma source modification factor the USNS SGT. CHARLES E. MOWER	2.78 (Weitz, 2009)
$GSMF_{LAND}$	Gamma source modification factor land	1.0 (Weitz, 2009)

Table 5. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
$GSMF_{LSD}$	Gamma source modification factor the USS CABILDO	2.75 (Weitz, 2009)
$Frac_{SL}$	Fraction of time spent on shore liberty	4 hr every 4th day $0.0417 = 4/(24 \times 4)$
$K_{Ship}(t)$	Resuspension factor for resuspension of fallout from ship surfaces	$K = 10^{-5}$ for $t \leq 100$ hrs, 0 for $t > 100$ hrs (DTRA, 2010, SM ID01)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the GREENHOUSE ship-based personnel are summarized in Table 6. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing doses, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 6 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 6. External and Internal Doses and Upper-Bounds for GREENHOUSE Ship-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	3		7	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.002	<0.001	0.02
Bone Surface	0.01	0.02	0.1	0.2
Brain	<0.001	0.001	<0.001	0.01
Breast	<0.001	0.002	<0.001	0.02
Stomach Wall	<0.001	0.01	<0.001	0.1
Small Intestine Wall	<0.001	0.02	<0.001	0.2
Upper Large Intestine Wall	<0.001	0.07	<0.001	0.7
Lower Large Intestine Wall	<0.001	0.2	<0.001	2
Kidney	<0.001	0.002	<0.001	0.02
Liver	0.003	0.003	0.03	0.03
Extra-Thoracic Region	<0.001	0.2	0.001	2
Lung	<0.001	0.3	0.003	3
Muscle	<0.001	0.002	<0.001	0.02
Pancreas	<0.001	0.002	<0.001	0.02
Red Marrow	<0.001	0.006	0.005	0.06
Spleen	<0.001	0.002	<0.001	0.02
Testes	<0.001	0.001	0.002	0.009
Thymus	<0.001	0.002	<0.001	0.02
Thyroid	<0.001	0.3	<0.001	3
Urinary Bladder Wall	<0.001	0.006	<0.001	0.06

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 6 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 7. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 7. Cancer Cases not Recommended for Expedited Processing for GREENHOUSE Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	10

6. References

Berkhouse, L., Davis, S.E., Gladeck, F.R., Hallowell, J.H., Jones, C.B., Martin, E.J., McMullan, F.W., and Osborne, M.J., 1983. *Operation GREENHOUSE: 1951, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review.* DNA 6034F, Defense Nuclear Agency, Washington, D.C. June 15.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4.* DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Gminder, R., Stuart, J., Weitz, R., Goetz, J., and Klemm, J., 1982. *Analysis of Radiation Exposure for Naval Personnel at Operation GREENHOUSE*. DNA-TR-82-15, Defense Nuclear Agency, Washington, D.C. July 30.

Thomas, C., Stuart, J., Goetz, J., and Klemm, J., 1983, *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*. DNA TR-82-98, Defense Nuclear Agency, Washington, DC, March 15

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R. L., 2009. *Formulation of the Gamma Source Modification Factor (GSMF) for Ship-based Applications*. NTPR-TM-09-04, Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation GREENHOUSE Land-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group:
Operation GREENHOUSE Land-Based Personnel

1. Description of the Expedited Processing Group

The GREENHOUSE Land-Based Personnel Expedited Processing Group (EPG) consists of the personnel assigned to the units present at Enewetak Atoll, Bikati Island, Majuro Atoll, or Kwajalein Atoll during the operation, as listed in Table 1Table 1 below (Berkhouse et al., 1983, DTRA, 2008, Appendix B-3).

Table 1. Operation GREENHOUSE Land-Based Units

Unit	Location	Size
Headquarters (HQ) Joint Task Force 3	Parry Island	320
HQ TG 3.2 (Army)	Enewetak Island	68
79th Engineer Construction Battalion		64
7127th Army Unit to include the 7th Engineer Brigade, 8128th Army Unit, 70th Automotive Maintenance Ordnance Detachment, 7127th Communication Detachment, 7129th Army Unit, and 7130th Army Unit Special Services Detachment, 4th Transportation Truck Company	Enewetak Island	146
3rd Mobile Army Surgical Hospital	Enewetak Island	43
HQ 18th Transportation Corps Port Company	Enewetak Island	10
511th Transportation Corps Port Company	Enewetak Island	208
506th Counterintelligence Corps Detachment	Enewetak Island	10
516th Military Policy Service Company	Enewetak Atoll to include Parry and Japtan Islands.	228
TG 7.1 to include Office of the Quartermaster General, Signal Corps Engineering Laboratories, Army Chemical Center and Ballistic Research Laboratories	Enewetak Atoll	84
Navy personnel in Task Group 3.1	Enewetak Atoll	349
Air Transport Squadron 3	Enewetak Island	119
Air Force personnel in Task Group 3.1	Enewetak Atoll	125
Task Group 3.4.1 to include the 158th Fighter Squadron; 3204th Medical Group; 3200th Drone Squadron Detachment; and 634th, 645th, 646th, 647th, 648th, 653th, 654th, 655th, 656th, 658th, 660th, 661th, 667th, 669th, 670th, 677th Aircraft Control and Warning Squadrons	Enewetak Atoll	660
Task Group 3.4.1 Detachment	Kwajalein Island	232
Task Group 3.4.2 to include the 3200th Drone Squadron	Enewetak Island	649

Table 1. Operation GREENHOUSE Land-Based Units (cont.)

Unit	Location	Size
Task Group 3.4.2 Detachment to include the 3151st Electronic Group and the 3171st Electronic Research and Development Group	Kwajalein Island and Enewetak Island	98
Task Unit 3.4.3 to include the 1810th Airways and Air Communication Service (AACS) Group; and 1909th and 1960th AACS Squadrons	Enewetak Island with a detachment on Kwajalein Atoll	139
Task Unit 3.4.4 to include the 57th Strategic Reconnaissance Squadron	Kwajalein Atoll with a detachment on Enewetak Atoll	323
Task Unit 3.4.5 to include the 26th Weather Squadron; 2060th Mobile Weather Squadron; 1600th and 1701st Food Service Squadrons; 1801st and 1814th AACS Groups; 1901st, 1905th, 1907th, 1909th, 1922nd, 1923rd, and 1928th AACS Squadrons; and 1921-1, 1921-2, 1921-4, 1921-6, and 1921-9 AACS Detachments	Enewetak Island with detachments on Kwajalein, Kusaie, Nauru, Bikati, and Majuro Islands	105
Task Unit 3.4.6 to include the 2600th Air Base Squadron; 4415th and 4910th Air Base Groups; 4th Liaison Flights; and the 5th Helicopter Flight	Enewetak Atoll	107
Task Unit 3.4.7 to include the 4th Rescue Squadron, 5th Rescue Squadron, and 11th Air Rescue Squadron.	Kwajalein Island with Detachments on Enewetak Island	52
Task Unit 3.4.8 to include individuals from Air Force Lookout Mountain Laboratory.	Enewetak Island	30
Other Air Force units	Unknown	41
	Total	4210

The following individuals are excluded from expedited processing under this EPG:

- Individuals who participated in clothing contamination tests.

2. Basis of Dose Analysis for Operation GREENHOUSE Land-Based Personnel

To estimate EPG doses for GREENHOISE land-based personnel, the cohort that received the highest external residual radiation dose was identified and its exposure scenario reconstructed. For this EPG, the activities of Headquarters (HQ), Joint Task Force (JTF) 3 form the basis for the generic highest-dose cohort scenario (DTRA, 2008, Appendix B-3) for the following reason:

- The previous dose reconstructions have shown that personnel assigned to Parry Island at Enewetak Atoll received the highest doses.

As explained below, several dose components and assumptions were added to the documented HQ JTF 3 Parry Island resident scenario to produce EPG doses. The basic scenario of participation and radiation exposure of the HQ JTF-3 is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: HQ JTF-3

To estimate EPG doses for all military personnel assigned to islands in the PPG during Operation GREENOUSE, a generic high-sided exposure scenario was developed based on activities of HQ JTF 3 personnel on Parry Island, Enewetak Atoll. The HQ JTF 3 island residents on Parry Island worked in all areas of the JTF 3. (Berkhouse et al., 1983; DTRA, 2008, Appendix B-3)

HQ JTF 3 personnel on Parry Island were exposed to fallout from three GREENHOUSE shots (DTRA, 2008, Appendix B-3). Table 2 lists the fallout episodes on Parry Island. Figure 1 to Figure 3 display the peak radiation exposure rates on Parry Island due to each fallout event.

Table 2. Peak Radiation Exposure Rates on Parry Island during Operation GREENHOUSE

Shot	Peak Exposure Rate ($R\ hr^{-1}$)	Peak Exposure Rate Time (H+hr)
DOG	0.083	6
EASY	0.001	24
ITEM	0.118	14.7

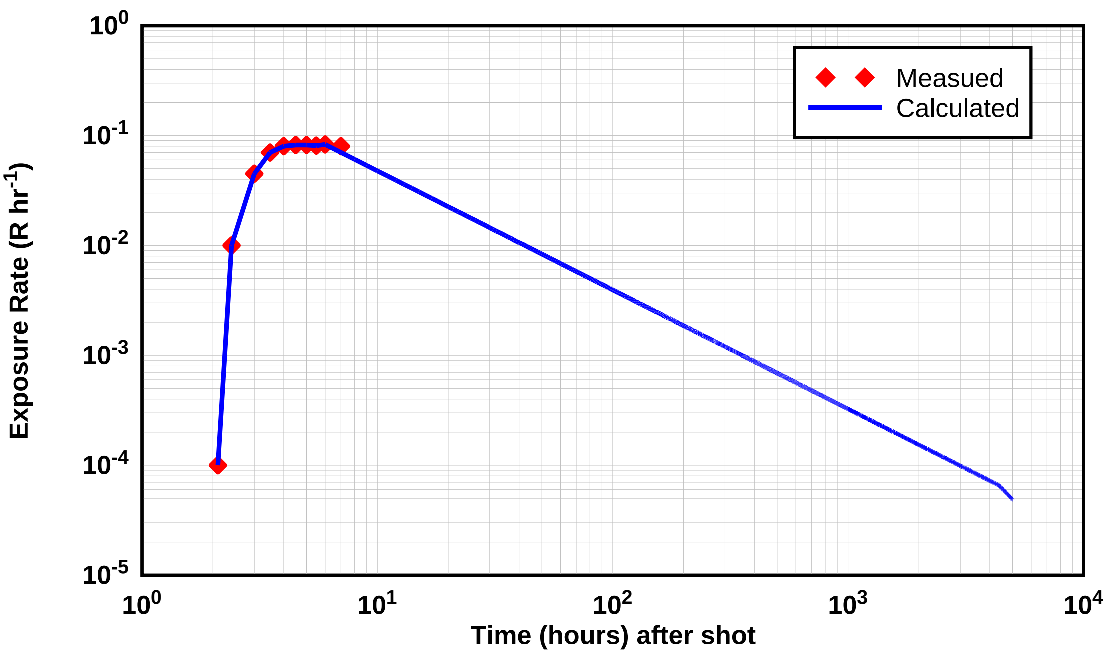

Figure 1. External Radiation Exposure Rate on Parry Island from Shot DOG

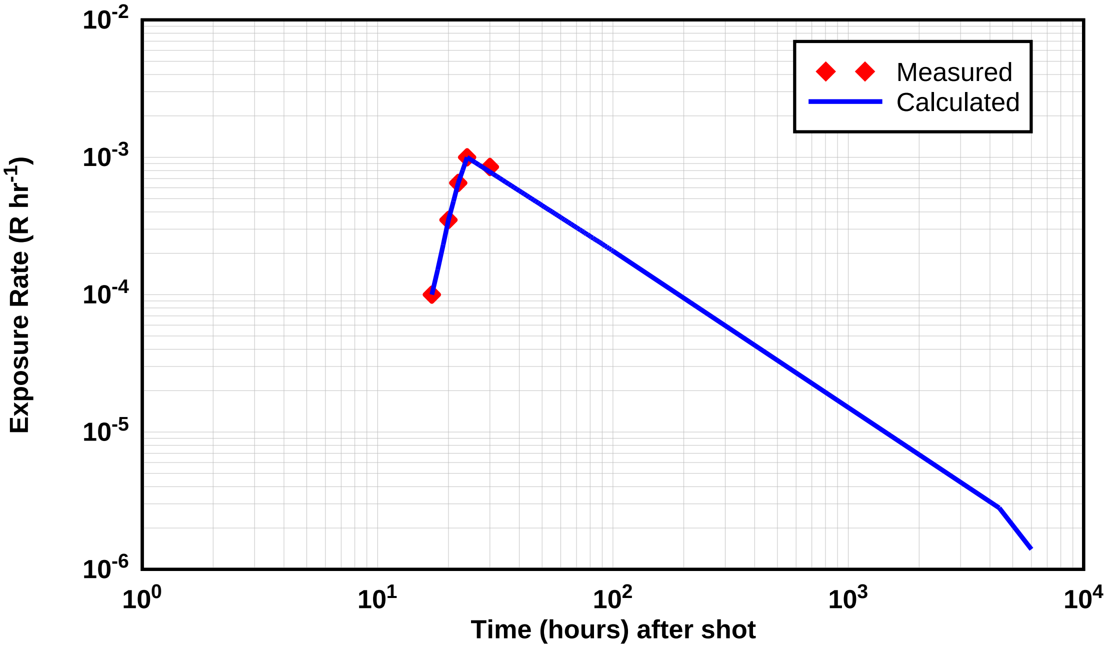

Figure 2. External Radiation Exposure Rate on Parry Island from Shot EASY

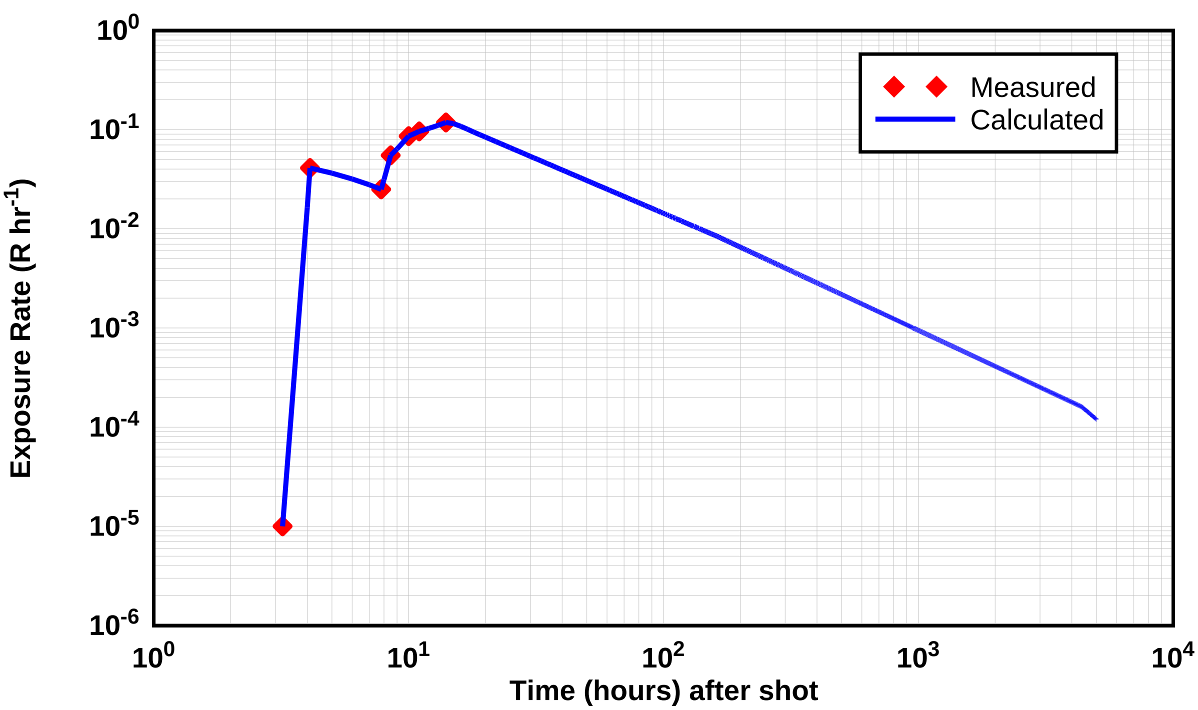

Figure 3. External Radiation Exposure Rate on Parry Island from Shot ITEM

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided HQ JTF 3 Parry Island resident cohort analysis. These are described below.

- The period of assignment is assumed to be from Jan 8, 1951 to May 31, 1952.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1} assuming that 8 hours were spent indoors for sleeping, cleaning and eating
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that they spent 100 percent of this time in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- Personnel are assumed to be outdoors during descending fallout and the fallout is considered light enough so that daily duty routines were not altered. (Thomas et al., 1984)
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 $m^3\ hr^{-1}$. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al. 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure Pathways for GREENHOUSE Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from Operation SANDSTONE shots	HQ JTF 3 personnel were exposed to fallout from Operation SANDSTONE Shots.	The number of hours spent topside was increased from 8 to 16 hr day^{-1}. Assumed a protection factor of 0.15 for all structures.
Residual radiation from three shots during Operation GREENHOUSE	HQ JTF 3 personnel residents were exposed to fallout from Shots DOG, EASY, and ITEM during the operational period and post-operation period.	The number of hours spent topside was increased from 8 to 16 hr day^{-1}. Assumed a protection factor of 0.15 for all structures.
INTERNAL		
Inhalation of descending fallout from three fallout episodes	HQ JTF 3 personnel were subjected to descending fallout from Shots DOG, EASY, and ITEM.	Used a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout from Operation SANDSTONE shots	HQ JTF 3 personnel were subjected to inhalation of resuspended fallout from Operation SANDSTONE shots.	Used a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout from three GREENHOUSE shots	HQ JTF 3 personnel were subjected to inhalation of resuspended fallout from Shots DOG, EASY, and ITEM	Used a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from Operation SANDSTONE shots	HQ JTF 3 personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Operation SANDSTONE shots	
Incidental ingestion of contaminated soil/dust from GREENHOUSE shots	HQ JTF 3 personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots DOG, EASY, and ITEM	

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$	Enewetak arrival date	8 Jan 1951[0000]
$Date_{StartOp}$	GREENHOUSE start date[time]	8 Apr 1951[0634]
$Date_{EndOp}$	GREENHOUSE end date[time]	31 May 1951[2400]
$Date_{Departed}$	Enewetak departure date[time]	31 May 1952[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Atoll	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
PF_t	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
$IpeakDet_{DG}$ $TpeakDet_{DG}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot DOG	0.083 R hr^{-1} at H+6 (DTRA, 2008, Appendix B-3)
$IpeakDet_{ES}$ $TpeakDet_{ES}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot EASY	0.001 R hr^{-1} at H+24 (DTRA, 2008, Appendix B-3)
$IpeakDet_{IT}$ $TpeakDet_{IT}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ITEM	0.118 R hr^{-1} at H+14 (DTRA, 2008, Appendix B-3)
λ_{DG}	Decay exponent for times less than H+ 4380 for Shot DOG	1.083 (DTRA, 2008, Appendix B-3)
λ_{ES}	Decay exponent for times less than H+ 4380 for Shot EASY	1.1 (DTRA, 2008, Appendix B-3)
λ_{IT}	Decay exponent for times less than H+ 4380 for Shot ITEM	1.1 (DTRA, 2008, Appendix B-3)
λ_{postop}	Decay exponent for times less than H+ 4380 for post operation periods	1.2 (DTRA, 2008, Appendix B-3)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-3)
$DoseDet_{Pre}$	External gamma dose due to fallout from Operation SANDSTONE residual radiation	0.001 rem (Mason, 2009)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
$DoseIntDet_{Pre}$	Internal doses due to fallout from Operation SANDSTONE residual radiation	(Mason, 2009)

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
DCF_{Inhfbe} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 μm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the GREENHOUSE land-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing doses, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for Operation GREENHOUSE Land-Based Personnel

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	7		21	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.02	0.005	0.2
Bone Surface	0.3	0.2	3	2
Brain	<0.001	0.008	0.005	0.08
Breast	<0.001	0.02	0.005	0.2
Stomach Wall	<0.001	0.09	0.005	0.9
Small Intestine Wall	<0.001	0.2	0.005	2
Upper Large Intestines Wall	<0.001	0.5	0.005	5
Lower Large Intestines Wall	<0.001	0.9	0.005	8
Kidney	0.002	0.02	0.02	0.2
Liver	0.06	0.03	0.6	0.3
Extra-Thoracic Region	0.003	2	0.03	12
Lung	0.006	2	0.06	15
Muscle	<0.001	0.02	0.005	0.2
Pancreas	<0.001	0.02	0.005	0.2
Red Marrow	0.02	0.06	0.2	0.5
Spleen	<0.001	0.02	0.005	0.2
Testes	0.004	0.007	0.04	0.06
Thymus	<0.001	0.02	0.005	0.2
Thyroid	<0.001	2	0.005	16
Urinary Bladder Wall	<0.001	0.05	0.005	0.4

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 5 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 6. Cancer Cases not Recommended for Expedited Processing for Operation GREENHOUSE Land-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Liver	Liver	22
Gall Gladder	Liver	22
Bile Duct	Liver	22
Thyroid	Thyroid	37
Total EPG upper-bound dose below but close to the screening dose		
Lung	Lung	36
Esophagus	Extra-Thoracic Region	33
Acute Lymphocytic Leukemia	Red Bone Marrow	22
Colon	Lower Large Intestine Wall	29
Stomach Wall	Stomach Wall	22
Parathyroid	Thyroid	37

6. References

Berkhouse, L.; Davis, S.E.; Gladeck, F.R.; Hallowell, J.H.; Jones, C.B.; Martin, E.J. ; McMullan, F.W.; and Osborne, M.J., 1983. *Operation GREENHOUSE: 1951, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review.* DNA 6034F, Defense Nuclear Agency, Washington, DC. June 15.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA

Mason, C, 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02, Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4.* DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J., Klemm, J., and Weitz, R., 1984. *Analysis of Radiation Exposure for Naval Personnel at Operation CASTLE*. DNA-TR-84-6, Defense Nuclear Agency, Washington, DC. February 28.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R. L., and Egbert, S. D., 2009. *Compilation of Initial Radiation Doses to Atmospheric Test Participants*. NTPR-TM-09-01, Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation IVY Ship-Based Personnel

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

Expedited Processing Group:
Operation IVY Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation IVY Ship-Based Personnel Expedited Processing Group (EPG) consists of approximately 4,700 personnel who were assigned to U.S. Navy and U.S. Army ships during Operation IVY (1952) (Gladeck et al., 1982; Thomas et al., 1983). Although general activities of the crew members of the various ships in this EPG were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure of these participants involving relevant IVY shots were similar. Therefore it is reasonable to include most participants assigned to ship crews during Operation IVY into a single EPG.

The IVY test series of two detonations was conducted from November 1 to 18, 1952 at Enewetak Atoll in the Pacific Proving Ground (PPG). Joint Task Force 132 (JTF 132) was responsible for the conduct of the operation and consisted of elements of all four military services, the Atomic Energy Commission (AEC), and Federal civilian agencies and their contractors. JTF 132 was organized into functional and service branch oriented task groups (TG), although there were cross-service TG assignments. Ship-based personnel were assigned to TG 132.3, and consist primarily of naval personnel but also include members of the other services. The TG 132.3 ships included in this EPG are listed in Table 1 (Gladeck et al., 1982; DTRA, 2008, Appendix B-4; Thomas et al., 1983). There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for IVY Ship-Based Personnel

To estimate EPG doses for all Operation IVY ship-based personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose. This cohort is referred to as the “highest-dose cohort.” Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a “highest-dose cohort” because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, personnel assigned to USS LIPAN form the basis for the exposure scenario of the highest-dose cohort (Thomas et al., 1983) for two primary reasons:

- The crew members received the largest average external gamma dose from residual radiation for all IVY ship-based personnel,
- The operating history of the ship is well-documented

Table 1. Ships Assigned to Task Group 132.3 at Operation IVY

Ship	Task Element	Size
USS AGAWAM (AOG-6)	132.32 (Service & Harbor Control)	122
USS ARIKARA (ATF-98)	132.32 (Service & Harbor Control)	80
USS CARPENTER (DDE-825)	132.33 (Destroyer Element)	276
USS CURTISS (AV-4)[3]	132.30 (Weapons Element)	722
USNS DAVID C. SHANKS (TAP-180)	132.31 (Transport Element)	191
USS ELDER (AN-20) [2]	132.31 (Transport Element)	49
USS ESTES (AGC-12)	132.31 (Transport Element)	566
USS FLETCHER (DDE-448)	132.33 (Destroyer Element)	258
USNS GENERAL E.T. COLLINS (TAP-147)	132.31 (Transport Element)	192
M/V HORIZON (ex ATA)	132.32 (Service & Harbor Control Element)	26*
USS LEO (AKA-60)	132.31 (Transport Element)	228
USS LIPAN (ATF-85)	132.32 (Service & Harbor Control Element)	79
USS LST-836[4]	132.31 (Transport Element)	129
USS OAK HILL (LSD-7)	132.32 (Service & Harbor Control Element)	230
USS O'BANNON (DDE-450)	132.33 (Destroyer Element)	251
USS RADFORD (DDE-446)	132.33 (Destroyer Element)	256
USS RENDOVA (CVE-114)	132.34 (Convoy and Escort Element)	876
M/V SPENCER F. BAIRD (ex ATA)	132.32 (Service & Harbor Control Element)	21*
TG 132.3 Boat Pool (LCU-666, LCU-667, LCU-709, LCU-764, LCU-851; 3 AVRs, 19 LCMs, 4 LCP(L)s	132.32 (Service & Harbor Control)	45†
USS YUMA (ATF-94)	132.32 (Service & Harbor Control Element)	76
YOG-69	132.32 (Service & Harbor Control Element)	14
	Total	4,687

* Civilian crews not included.
† Number of LCU crew members only (Gladeck et al., 1982).

As explained below, several dose components and assumption were added to the documented USS LIPAN scenario (Thomas et al., 1983) to produce EPG doses. The basic scenario of participation and radiation exposure of the USS LIPAN is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Crew of USS LIPAN

To estimate EPG doses for all military personnel assigned to ships during Operation IVY, a generic high-sided exposure scenario was developed based on activities of crew members of USS LIPAN. USS LIPAN was a fleet ocean tug that arrived at Enewetak Atoll on October 20, 1952, and served in the Towing Unit of the Service and Harbor Control Element (Task Element 132.32). Its primary function was to provide the task force with towing and salvage services.

When MIKE was detonated at 0715 on November 1, 1952, USS LIPAN was at sea at a distance of approximately 25 nautical miles east of the surface zero on Elugelab Island. Prior to its return to the Enewetak Lagoon, USS LIPAN operated in the contaminated waters close to the MIKE test site area. As a result, USS LIPAN became contaminated, with most of the contamination confined to the evaporators, fire and flushing system, anchor chain, and the exterior of the hull below the waterline. USS LIPAN reentered Enewetak Lagoon on

November 2, 1952, and moored off of Enewetak Island, about 25 nautical miles southeast of the MIKE crater. When KING was detonated at 1130 on November 16, 1952, USS LIPAN was at sea 19 nmi south-southeast of the airburst over Runit Island. USS LIPAN reentered Enewetak Lagoon later that same day and anchored off of Enewetak Island. The crew was presumably allowed shore liberty on Enewetak Island or Parry Island during times that the ship was anchored in the lagoon. The ship was given an operational radiological clearance on November 17, 1952. USS LIPAN departed from Enewetak on November 18, 1952, enroute to Guam, where it arrived on November 26, 1952 (Gladeck et al., 1983; DTRA 2008, Appendix B-4; Thomas et al., 1983).

USS LIPAN did not receive any primary (early-time) fallout from either IVY shot; secondary (late-time) fallout is the only fallout experienced by the ship. Both IVY shots also resulted in fallout at the shore liberty islands of Enewetak Atoll. The two sources of exposure to crewmembers of USS LIPAN were fallout from IVY shots while on board the ship and fallout on liberty islands. Average fallout exposure rates measured on the Enewetak Island are applicable to USS LIPAN and other ships anchored in the vicinity. The IVY shots and the resulting fallout exposure rates for USS LIPAN are shown in Table 2 (note that there were two episodes of Shot MIKE fallout). The time-dependent fallout exposure rates on USS LIPAN due to fallout from the two IVY shots are shown in Figure 1 and Figure 2 (DTRA, 2008, Appendix B-4).

Table 2. Operation IVY Shots and Resulting Fallout Exposure Rates on USS LIPAN

Shot	Shot Date (1952) and Time	Peak Exposure Rate (R hr^{-1})	Peak Time (H+hr)
MIKE*	November 1 at 0715	0.00063 0.00004	77 168
KING	November 16 at 1130	0.00012	24

* Two separate fallout waves

Figure 1. Average Topside Residual Radiation Exposure Rate on USS LIPAN following both Waves of Fallout from Shot MIKE

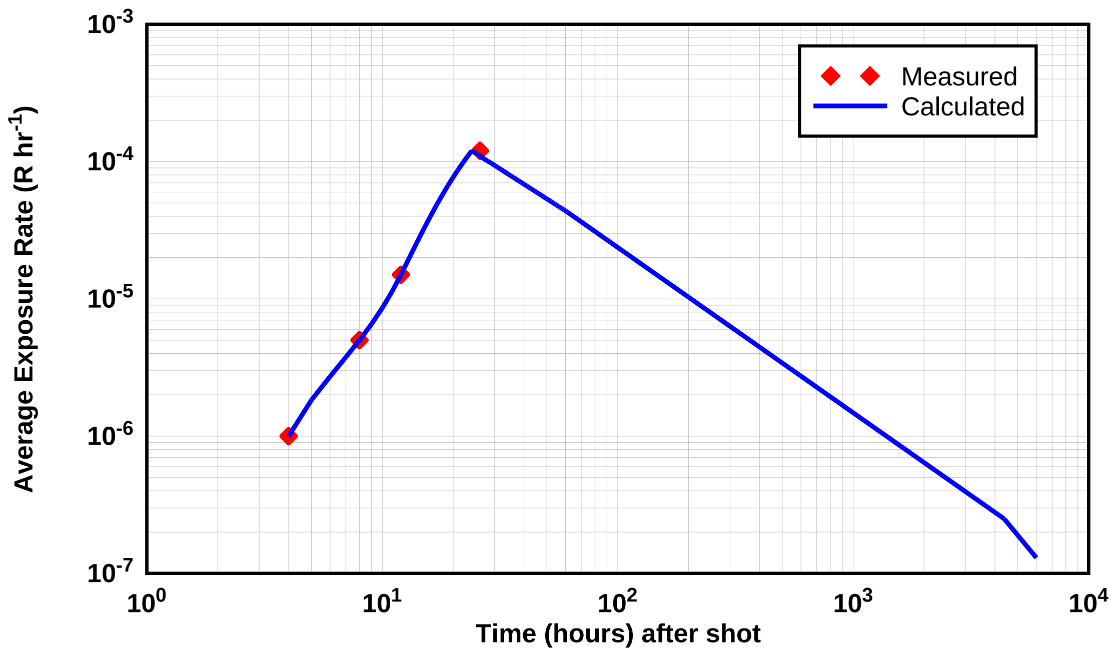

Figure 2. Average Topside Exposure Rate on USS LIPAN from Shot KING

Based on these exposure rates, decayed to the end of the operation and then one year beyond, the crew of USS LIPAN accrued external doses from deposited fallout while topside and below deck while on board. An additional source of external dose to crew members was from deposited fallout at the liberty islands. The crew of USS LIPAN received internal doses from resuspended fallout during their time topside while on board ship and during their time out of doors while on shore liberty, and from incidental ingestion of contaminated soil and dust during shore liberty (DTRA, 2008, Appendix B-4).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions, as described below, were added to the highest-dose cohort analysis:

- The period of exposure was from prior to the first fallout event until November 18, 1953.
- The number of hours spent topside is increased from 14.4 to 16 hr day^{-1}, while 8 hours per day were spent below deck for sleeping, cleaning and eating.
- Periodic closures of the shore liberty recreational facilities are ignored, and personnel are assumed to have used shore recreational facilities during the entire operational period.
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.
- No parameter assumption for the ship shielding factor for this scenario was necessary. The ship shielding factor for the USS LIPAN is 0.15 (fraction transmitted to below-deck spaces) and is already the largest reasonable value (DTRA, 2008, Appendix B-4).

Exposure pathways for the EPG scenario are described in Table 3. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure pathways for the Operation IVY Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from deposited fallout while topside during and after Operation IVY	USS LIPAN crew members were exposed to residual radiation due to fallout from Shots MIKE and KING while topside during the operational period.	Time topside is 16 hr day^{-1} instead of 9.6 hr day^{-1}. The period of assignment was extended to one year after the end of Operation IVY.
Residual radiation from deposited fallout while below deck during and after Operation IVY	USS LIPAN crew members were exposed to residual radiation due to fallout from Shots MIKE and KING while below deck during the operational period.	Used the below-deck dose shielding factor of 0.15 (fraction transmitted) for time spent below deck. The period of assignment was extended to one year after the end of Operation IVY
Residual radiation from deposited fallout while on shore liberty during Operation IVY	USS LIPAN crew members were exposed to fallout from Shots MIKE and KING while on shore liberty at Enewetak Atoll during the operational period.	Assumed shore leave every 4th day for four hours.
INTERNAL		
Inhalation of resuspended fallout from three fallout episodes while topside	USS LIPAN crew members inhaled resuspended fallout from Shots MIKE and KING until 100 hours after the time of peak fallout.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Time topside is 16 hr day^{-1} instead of 9.6 hr day^{-1}.
Inhalation of resuspended fallout during shore liberty periods	USS LIPAN crew members inhaled resuspended fallout from Shots MIKE and KING while on shore liberty at Enewetak Atoll during the operational period.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed shore leave every 4th day for four hours. .
Incidental ingestion of contaminated soil/dust from two fallout episodes	USS LIPAN crew members ingested soil and dust at Enewetak Atoll contaminated with fallout from Shots MIKE and KING while on shore liberty at Enewetak Atoll during the operational period.	Assumed shore leave every 4th day for four hours. .

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartOp}$	IVY start date[time]	1 Nov 1952[0715]
$Date_{EndOp}$	IVY end date[time]	18 Nov 1952[2400]
$Date_{Departed}$	Enewetak Atoll departure date[time]	18 Nov 1953[2400]
EXTERNAL		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
SF	Shielding factor while below deck	0.15 (Thomas et al., 1983)
$IpeakDet_{MK1}$ $TpeakDet_{MK1}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MIKE (first episode) aboard ship and at Enewetak Atoll during shore liberty	0.00063 R hr^{-1} at H+77 (DTRA, 2008, Appendix B-4)
$IpeakDet_{MK2}$ $TpeakDet_{MK2}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MIKE (second episode) aboard ship and at Enewetak Atoll during shore liberty	0.0004 R hr^{-1} at H+168 (DTRA, 2008, Appendix B-4)
$IpeakDet_{KG}$ $TpeakDet_{KG}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot KING aboard ship and at Enewetak Atoll during shore liberty	0.00012 R hr^{-1} at H+24 (DTRA, 2008, Appendix B-4)
λ_{postop}	Decay exponent for times less than H+ 4380	1.2 (DTRA, 2008, Appendix B-4)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-4)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
GSMF	Gamma source modification factor for location of exposure rate measurement	1.0 (DTRA, 2010, SM ED02)
F_{ts}	Fraction of time spent topside (time exposed to resuspended fallout)	0.67 (= 16/24)
$Frac_{SL}$	Fraction of time spent on shore liberty	0.0417 [4 hr every 4^{th} day = 4/(24 × 4)]
K_{Ship}	Resuspension factor for resuspension of fallout from ship surfaces	$K = 10^{-5}$ (DTRA, 2010, SM ID01)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate during shore liberty periods	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density during shore liberty periods	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
DCF_{inhFBE} DCF_{inhAct} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the IVY ship-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for Operation IVY Ship-Based Personnel

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	0.07		0.2	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	<0.001	<0.001	<0.001
Bone Surface	0.003	0.002	0.03	0.02
Brain	<0.001	<0.001	<0.001	<0.001
Breast	<0.001	<0.001	<0.001	<0.001
Stomach Wall	<0.001	<0.001	<0.001	0.002
Small Intestine Wall	<0.001	<0.001	<0.001	0.004
Upper Large Intestine Wall	<0.001	0.002	<0.001	0.02
Lower Large Intestine Wall	<0.001	0.004	<0.001	0.04
Kidney	<0.001	<0.001	<0.001	<0.001
Liver	<0.001	<0.001	0.005	0.004
Extra-Thoracic Region	<0.001	0.005	<0.001	0.05
Lung	<0.001	0.008	<0.001	0.08
Muscle	<0.001	<0.001	<0.001	<0.001
Pancreas	<0.001	<0.001	<0.001	<0.001
Red Marrow	<0.001	<0.001	0.002	0.002
Spleen	<0.001	<0.001	<0.001	<0.001
Testes	<0.001	<0.001	<0.001	<0.001
Thymus	<0.001	<0.001	<0.001	<0.001
Thyroid	<0.001	0.005	<0.001	0.05
Urinary Bladder Wall	<0.001	<0.001	<0.001	<0.001

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01. Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Gladeck, F.R., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.H., Pozega, R., Rogers, W.E., Rowland, R.H., Shelton, L., Berkhouse, L., Davis, S.E., Doyle. M.K., and Jones, C.B., 1982. *Operation IVY: 1952*. DNA 6036F. Defense Nuclear Agency, Washington, DC. December 1.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11. Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J., Stuart, J., and Klemm, J., 1983. *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*. DNA-TR-82-98. Defense Nuclear Agency, Washington, DC. March 15.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13. Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1)*. NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation IVY
Land-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation IVY Land-Based Personnel

1. Description of the Expedited Processing Group

The Operation IVY Land-Based Personnel Expedited Processing Group (EPG) consists of most of the military personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak and Parry Islands), Kwajalein Atoll, and the so-called "weather" atolls of Ponape, Kusaie, Majuro, and Bikini in support of Operation IVY during any period of that operation. Manned weather stations were established on Ponape (approximately 500 nmi southwest of Enewetak), Kusaie (approximately 400 nmi south of Enewetak), Majuro (approximately 600 nmi southeast of Enewetak), and Bikini (approximately 200 nmi east of Enewetak) (DTRA, 2008, Appendix B-4; Gladeck et al., 1982; Thomas et al., 1983).

Operation IVY was the series of atmospheric nuclear weapon tests conducted in November 1952 by the Atomic Energy Commission (AEC) with participation from the Department of Defense (DoD) at Enewetak Atoll in the Pacific Proving Ground (PPG). Units included in this EPG consist of the land-based units of all the tasks groups that participated in Operation IVY, which are listed in Table 1, along with their sizes (DTRA, 2008, Appendix B-4; Gladeck et al., 1982).

Although general activities of the personnel in this EPG were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure of these participants involving IVY shots were similar. Therefore it is reasonable to include most participants assigned to one of the residence islands at Enewetak or Kwajalein Atoll or on one of the "weather" islands during Operation IVY into a single EPG (Gladeck et al., 1982; DTRA, 2008, Appendix B-4). There are no specific exclusions for this EPG.

Table 1. Land-Based Units and Military Personnel of JTF 132 Task Groups at Operation IVY

Task Group (TG)*	Units	Size
TG 132.1 (Scientific) [E]	Army (miscellaneous) Navy (miscellaneous) Air Force Marines	105 80 33 4
TG 132.2 (Army) [E]	Headquarters Task Group 132.2 (7126th AU) Temporary duty from U.S. Army, Pacific 7131st Army Unit Signal Detachment 7131st Army Unit Signal Detachment 516th Military Police Company Communications Security Detachment 1, 8607th AAU 18th Military Police Criminal Investigation Division Counterintelligence Corps, Provisional, Sub-Detachment C 125th Military Police, Provost Marshal Detachment 511th Transport Port Company 4th Transport Truck Company	1,196
	Air Force	2
	Navy:	2
	Coast Guard: Loran Station Detachment [E]	9
TG 132.3 (Navy)	Navy: Boat Pool [E] Underwater Detection Unit [E] Patrol Plane Unit [K] Air Transport Units (Non-JTF 132) [K] Fleet Post Office (FPO) 824 [K]	656
	Marines: Kwajalein Naval Base	93
TG 132.4 (Air Force) [K]	Kwajalein: Headquarters Task Group 132.4: Air Force Special Weapons Center 4925th Test Squadron Test Support Unit 4930th Test Support Squadron 4908th Motor Vehicle Squadron Test Aircraft Unit (TAU): Headquarters Strategic Air Command 3902nd Air Base Wing 12th Air Division 93rd Bombardment Wing Sampler Element: 12th Fighter-Escort Wing 27th Fighter Wing 561st Fighter-Escort Squadron Drop Element: 7th Bombardment Wing 11th Bombardment Wing 42nd Bombardment Squadron 19th Air Division Control & Tanker Element: 307th Air Refueling Squadron 509th Bombardment Wing	2,073

* E = Enewetak Atoll, K = Kwajalein, W = “weather” islands of Ponape, Kusaie, Majuro, and Bikini.

Table 1. Land-Based Units and Military Personnel of JTF 132 Task Groups (cont.)

Task Group (TG)*	Units	Size
TG 132.4 (Air Force) [K] (cont.)	Effects Element: 6520th Flight Test Squadron Air Force Cambridge Research Center Air Research and Development Center 3160th Electronic Group Wright Air Development Center Test Services Unit: 47th Air Transport Squadron 48th Air Transport Squadron 50th Air Transport Squadron 1254th Air Transport Squadron MATS Pacific Division Weather Reconnaissance Element: 57th Strategic Reconnaissance Squadron Weather Reporting Element [E, K, W]*: 6th Weather Squadron 9th Weather Group (Weather Reporting Element) 1500th Weather Reporting Squadron Communications Element: 1810th Airways & Air Comm Service Squadron Search and Rescue Element: 11th Air Rescue Squadron Photo Element: 6th Air Division 306th Bombardment Wing 2nd Bombardment 338th Strategic Reconnaissance Squadron 1352nd Motion Picture Squadron 523rd Motion Picture Squadron 15th Bombardment Wing USAF Lookout Mountain Laboratory	
TG 132.4 (Air Force) [E]	Enewetak: Test Support Unit 4930th Test Support Squadron 4908th Motor Vehicle Squadron Test Services Unit Weather Reporting Element: 6th Weather Squadron (Weather Reporting Element) 9th Weather Group (Weather Reporting Element) Communications Element: 1810th Airways & Air Communications Service Squadron	355
TG 132.4 (Air Force) [W]	Weather Islands: Test Services Unit 6th Weather Squadron (Weather Reporting Element) 9th Weather Group (Weather Reporting Element) 1810th Airways and Air Communications Service Squadron	84
	Total	4,692

* E = Enewetak Atoll, K = Kwajalein, W = "weather" islands of Ponape, Kusaie, Majuro, and Bikini.

2. Basis of Dose Analysis for the IVY Land-Based Personnel

To estimate EPG doses for all Operation IVY Land-Based Personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort." Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of the 7126th Army Unit (AU) form an adequate basis of the generic highest-dose cohort scenario for this EPG for three primary reasons:

- This group was the largest single cohort that was in residence on Enewetak Atoll.
- The group was in residence at Enewetak Atoll for the entire time of Operation IVY.
- Most of the subunits of the 7126th Army Unit were not involved in radiological safety activities such as monitoring or decontamination that would increase the dose received well above other members of the cohort.

As explained below, several dose components and assumptions were added to the documented 7126th Army Unit scenario (Gladeck et al., 1982). The basic scenario of participation and radiation exposure of the 7126th Army Unit scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: 7126th Army Unit

To estimate EPG doses for all military personnel assigned to land-based units during Operation CASTLE, a generic high-sided exposure scenario was developed based on the activities of the 7126th AU.

Approximately 500 members of the Army were assigned to the 7126th AU, the core of the Army Task Group, during Operation IVY. Most service members assigned to the 7126th AU arrived before November 1, 1952 and stayed until the end of the operation on November 18, 1952. Members of the 7126th AU lived in tents or barracks on Enewetak and Parry Islands and had their meals in indoor dining facilities (DTRA, 2008, Appendix B-4; Gladeck et al., 1982).

For Shot MIKE, nearly all land-based personnel embarked on task force ships and evacuated to sea at distances of least 25 nautical miles (nmi) south and east of the lagoon prior to Shot MIKE. A few personnel remained on Enewetak Island during MIKE to man the airstrip for potential emergency landings. The ships returned to the atoll and reentered the lagoon the day following MIKE, allowing the embarked land-based personnel to return to duty. Land-based personnel stationed at Enewetak Atoll were not evacuated for Shot KING and remained ashore during the detonation at distances of at least 10 nmi from the surface zero (SZ) (DTRA, 2008, Appendix B-4; Gladeck et al., 1982).

Enewetak Atoll was directly affected by both IVY shots. Secondary fallout from Shot MIKE was the primary contributor to the low-level radiation encountered on Enewetak Atoll and arrived in two episodes or "waves." Being an airburst, Shot KING produced little fallout. Even so, Enewetak Atoll encountered a trace amount of fallout. Fallout from both IVY detonations that descended on Enewetak Atoll was a source of residual radiation that contributed to the dose accrued by members of this EPG. The peak radiation exposure rates at Enewetak Island during IVY are listed in Table 2 (DTRA, 2008, Appendix B-4; Gladeck et al., 1982).

Table 2. IVY Peak Exposure Rates for Enewetak Island

Shot	Peak Exposure Rate (R hr^{-1})	Hours After Shot (H+hr)
MIKE*	0.00063 0.00004	77 168
KING	0.00012	24

* Two separate fallout waves

The time series of radiation exposure rates on Enewetak Island for these three fallout events are shown in Figure 1 and Figure 2.

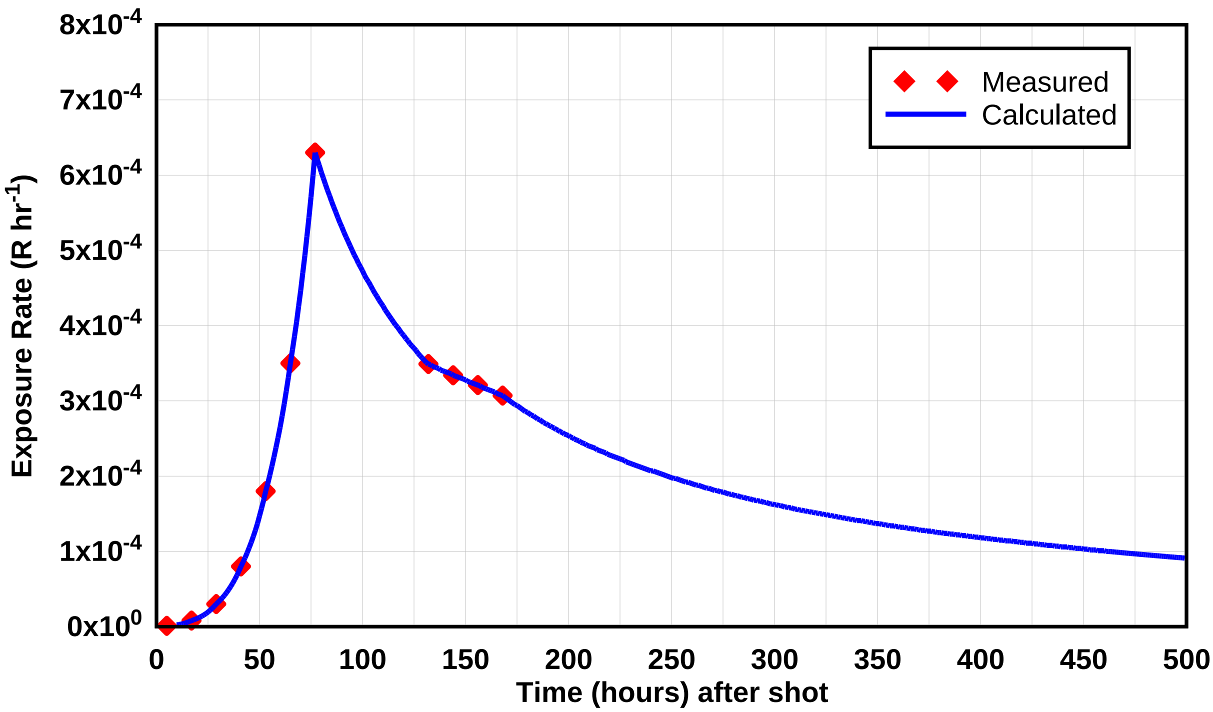

Figure 1. Residual Exposure Rate on Enewetak Island following both Waves of Fallout from Shot MIKE

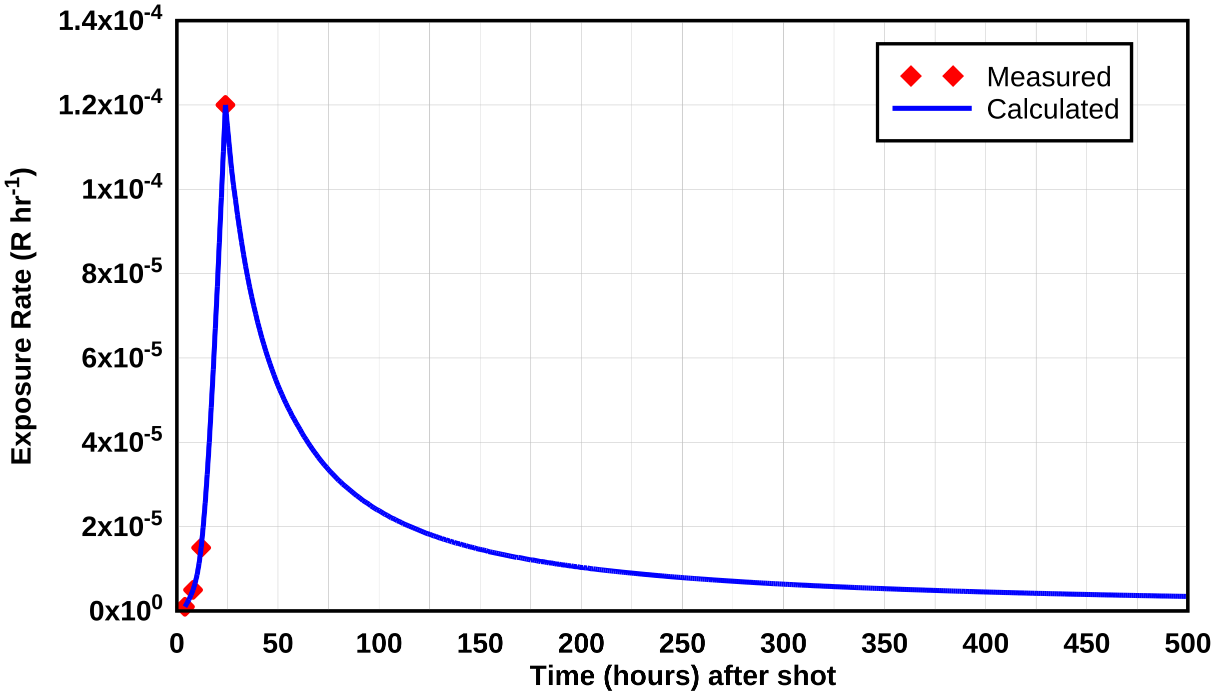

Figure 2. Residual Exposure Rate on Enewetak Island from Shot KING

Based on these exposure rates, decayed to the end of the operation and then one year beyond, Enewetak Atoll residents accrued external doses from deposited fallout while outside and while indoors. They also received internal doses while outdoors from inhalation of resuspended fallout and incidental ingestion of contaminated soil and dust during the same period (DTRA, 2008, Appendix B-4).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided 7126th AU cohort analysis:

- The period of assignment to Enewetak Atoll is assumed to include the entire IVY operational period. The assignment period used is three months prior to Shot MIKE, specifically August 1, 1952, to one year after the end of the operational period, specifically November 18, 1953 (DTRA, 2008, Appendix B-4).
- The number of hours spent outdoors is increased from the nominal value of 14.4 hr day^{-1} to 16 hr day^{-1}.
- Although personnel spend their time indoors in either a tent or a metal building, it is assumed that they spent 100 percent of this time in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.

- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 $m^3 hr^{-1}$. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 3. Exposure Pathways for the Operation IVY Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL DOSE		
Residual radiation from fallout from the previous operation's shots	7126th AU personnel were exposed to residual radiation due to fallout from Operation GREENHOUSE shots throughout their period of residence.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2. Arrival is three months prior to the start of operation (August 1, 1952) instead of actual arrival date. Departure is one year following the end of Operation IVY (November 18, 1953) instead of actual departure date.
Residual radiation from IVY fallout deposited on the residence islands of Enewetak Atoll	7126th AU personnel were exposed to residual radiation due to fallout from Shots MIKE and KING during the operational period until their departure.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Departure is one year following the end of Operation IVY (November 18, 1953) instead of actual departure date. Building protection factor is 1.5 instead of 2.
INTERNAL DOSE		
Inhalation of descending fallout from three fallout episodes	7126th AU personnel were subjected to inhalation of descending fallout from Shots MIKE and KING.	Breathing rate is 2 $m^3 hr^{-1}$ instead of 1.2 $m^3 hr^{-1}$.
Inhalation of resuspended fallout from previous operation's shots	7126th AU personnel were subjected to inhalation of resuspended fallout from Operation GREENHOUSE shots throughout their period of residence.	Breathing rate is 2 $m^3 hr^{-1}$ instead of 1.2 $m^3 hr^{-1}$. Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Arrival is three months prior to the start of operation (August 1, 1952) instead of actual arrival date. Departure is one year following the end of Operation IVY (November 18, 1953) instead of actual departure date.

Table 3. Exposure Pathways for the Operation IVY Land-Based Personnel (cont.)

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
INTERNAL DOSE		
Inhalation of resuspended fallout from current operation's shots	7126th AU personnel were subjected to inhalation of resuspended fallout from Shots MIKE and KING during the operational period until their time of departure.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Departure is one year following the end of Operation IVY (November 18, 1953) instead of actual departure date.
Incidental ingestion of contaminated soil/dust from fallout from previous operation's shots	7126th AU personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Operation GREENHOUSE shots throughout their period of residence.	Arrival is three months prior to the start of operation (August 1, 1952) instead of actual arrival date. Departure is one year following the end of Operation IVY (November 18, 1953) instead of actual departure date.
Incidental ingestion of contaminated soil/dust from fallout from current operation's shots	7126th AU personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots MIKE and KING during the operational period until their time of departure.	Departure is one year following the end of Operation IVY (November 18, 1953) instead of actual departure date.

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$	Enewetak arrival date	1 Aug 1952
$Date_{StartOp}$	IVY start date[time]	1 Nov 1952[0715]
$Date_{EndOp}$	IVY end date[time]	18 Nov 1952[2400]
$Date_{Departed}$	Enewetak departure date[time]	18 Nov 1953[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Atoll	0.67 (= 16/24)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
PF_t	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
$IpeakDet_{MK1}$ $TpeakDet_{MK1}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MIKE (first episode)	0.00063 R hr^{-1} at H+77 (DTRA, 2008, Appendix B-4)
$IpeakDet_{MK2}$ $TpeakDet_{MK2}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MIKE (second episode)	0.00004 R hr^{-1} at H+168 (DTRA, 2008, Appendix B-4)
$IpeakDet_{KG}$ $TpeakDet_{KG}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot KING	0.00012 R hr^{-1} at H+24 (DTRA, 2008, Appendix B-4)

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
EXTERNAL DOSE		
λ_{postop}	Decay exponent for times of H+ < 4380	1.2 (DTRA, 2008, Appendix B-4)
λ_{6mon}	Decay exponent for times of H+ > 4380	2.2 (DTRA, 2008, Appendix B-4)
$DoseDet_{Pre}$	External gamma dose due to fallout from Operation GREENHOUSE residual radiation prior to November 1, 1952	0.034 rem (DTRA, 2009b)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{inhAct} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)
$Int\ Dose_{PreOps}$	Internal doses due to fallout from Operation GREENHOUSE residual radiation	See (DTRA, 2009b) for a list of organ doses

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the IVY land-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for the Operation IVY Land-Based Personnel

External Doses	EPG Dose (rem)		Upper Bound EPG Dose (rem)	
Residual Gamma Radiation	0.2		0.4	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.003	0.002	0.02
Bone Surface	0.2	0.07	2	0.7
Brain	<0.001	0.001	0.002	0.007
Breast	<0.001	0.002	0.002	0.02
Stomach Wall	<0.001	0.005	0.002	0.04
Small Intestine Wall	<0.001	0.008	0.002	0.08
Upper Large Intestine Wall	<0.001	0.04	0.002	0.4
Lower Large Intestine Wall	<0.001	0.08	0.002	0.7
Kidney	<0.001	0.002	0.004	0.02
Liver	0.03	0.02	0.3	0.2
Extra-Thoracic Region	0.002	0.1	0.02	1
Lung	0.003	0.3	0.03	3
Muscle	<0.001	0.002	0.002	0.02
Pancreas	<0.001	0.002	0.002	0.02
Red Marrow	0.006	0.008	0.06	0.08
Spleen	<0.001	0.002	0.002	0.02
Testes	0.002	0.001	0.02	0.009
Thymus	<0.001	0.002	0.002	0.02
Thyroid	<0.001	0.08	0.002	0.8
Urinary Bladder Wall	<0.001	0.002	0.002	0.02

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment – Nuclear Test Personnel Review Program*, Revision 1.2, Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment - Nuclear Test Personnel Review Program, Revision 1.3/1.3a*, DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Gladeck, F.R., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.H., Pozega, R., Rogers, W.E., Rowland, R.H., Shelton, L., Berkhouse, L., Davis, S.E., Doyle, M.K., and Jones, C.B., 1982. *Operation IVY: 1952, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review*, DNA 6036F, Defense Nuclear Agency, Washington, D.C. December 1.

Mason, C, 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02, Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4). DTRA-TR-07-11 Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Stuart, J., Goetz, J., and Klemm, J., 1983, *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*, DNA TR-82-98, Defense Nuclear Agency, Washington, D.C. March 15.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation CASTLE High-Dose Ship-Based Personnel

November 2011

Important Note

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Expedited Processing Group: Operation CASTLE High-Dose Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation CASTLE High-Dose Ship-Based Personnel Expedited Processing Group (EPG) consists of approximately 1,350 military personnel who were assigned to certain U.S. Navy ships during Operation CASTLE (1954) (Martin and Rowland, 1982; DTRA, 2008, Appendix B-5). Operation CASTLE is described in Martin and Rowland (1982) and DTRA (2008, Appendix B-5).

Although general activities of the crew members of the various ships in this EPG were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure of these participants involving relevant CASTLE shots were similar. Therefore it is reasonable to include most high-dose (i.e., >2 rem external gamma dose due to higher fallout) ship crew members during Operation CASTLE in a single EPG.

The naval ships involved in Operation CASTLE experienced fallout from Shots BRAVO, ROMEO, YANKEE, NECTAR, and UNION. However, no ship received fallout from all five shots. In addition, the high-dose naval ships involved in Operation CASTLE list in Table 1 experienced radioactive hull contamination and shine from radioactive material floating in the water near the ship. (Martin and Rowland, 1982)

Table 1. Naval Ships that Participated in Operation CASTLE (High-Dose Ship-Based Personnel)

Ship	Arrival Date (1954)*	Departure Date (1954)	Duty (unit and Task Unit)	Size
USS BAIROKO (CVE 115)	Feb 20	May 17	7.3.2 Carrier Unit	892 plus 118 in the aviation unit
USS GYPSY (ARSD 1)	Jan 26	Mar 26	7.3.5 Utility Unit	62
USS PHILIP (DDE 498)	Jan 24	May 31	7.3.1 Surface Security Unit	274
			Total	1,346

* Some of the arrival dates are estimated from other ships.

The following individuals and units are excluded from expedited processing under this EPG:

- Ships that received light fallout that are in a distinct EPG (Operation CASTLE Low-Dose Ship-Based Personnel).
- Individuals who made shore excursions on Rongelap or Rongerik Atolls.
- Crew members of YAG 39 (USS GEORGE EASTMAN), USS PATAPSCO (AOG 1), or YAG 40 (GRANVILLE S. HALL).

2. Basis of Dose Analysis for Operation CASTLE High-Dose Ship-Based Personnel

To estimate EPG doses for all Operation CASTLE High-Dose Ship-Based Personnel, an exposure scenario was developed based on activities of the cohort group that received the highest dose from exposure to external residual radiation and corresponding internal doses. Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of the USS PHILIP form the basis for the generic highest-dose cohort scenario (DTRA, 2008, Appendix B-5) for two primary reasons:

- This group received the largest external gamma dose from residual radiation for all CASTLE High-Dose Ship-Based Personnel.
- The activities of this group are well-documented and are representative of other CASTLE High-Dose Ship-Based Personnel.

As explained below, several dose components and assumptions were added to the documented USS PHILIP scenario (Martin and Rowland., 1982) to produce EPG doses. The basic USS PHILIP scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: USS PHILIP Scenario

To estimate EPG doses for all military personnel assigned to high-dose U.S. Navy ships during Operation CASTLE, a generic high-sided exposure scenario was developed based on activities of the crew members of the USS PHILIP. The crew members of the USS PHILIP received the highest average external dose of any crew members in the Castle High-Dose Ship-Based Personnel EPG (DTRA, 2008, Appendix B-5). The fallout episodes experienced by the USS PHILIP are listed in Table 2 (DTRA, 2008, Appendix B-5).

The radiation exposure rates aboard USS PHILIP resulting from the two fallout events of Shots BRAVO and ROMEO are listed in Table 2 and are shown in Figure 1–Figure 2. These two fallout events were the only incidents of fallout deposited on the USS PHILIP. Based on these exposure rates, decayed to the end of the USS PHILIP participation, crew members accrued external doses from deposited fallout while topside and while below deck. They are assumed to have spent all day every day on board the ship during the period Mar 1–May 30, 1954, except for shore liberty. They also received internal doses while topside from inhalation of resuspended fallout for the first 100 hours after each fallout episode (Thomas et al., 1984 and DTRA, 2008, Appendix B-5).

Table 2. Peak Radiation Exposure Rates on USS PHILIP during Operation CASTLE

Shot	Shot Date (1954) (Time)	Peak Exposure Rate (R hr^{-1})	Time of Peak Exposure Rate (H+hr)
BRAVO	Mar 1 (0645)	0.75 0.25	2.25 17.25
ROMEO	Mar 27 (0630)	0.03 0.02	8.25 45.5

The USS PHILIP crew also accrued external doses from three other sources: accumulated radioactive materials on its underwater hull and in salt water piping and evaporators, radiation “shine” from contaminated lagoon water, and radioactive fallout in beach and shore areas during shore liberty. Although partially attenuated by the hull and piping structures, the gamma radiation emitted by these contaminants was a source of exposure to crewmembers in below-deck spaces. Crewmen who were topside when the ship operated in contaminated water were exposed to gamma radiation emitted directly from the contaminants in the water. Crew members were exposed to radioactive fallout while on Bikini and Enewetak Atoll during shore liberty (DTRA, 2008, Appendix B-5).

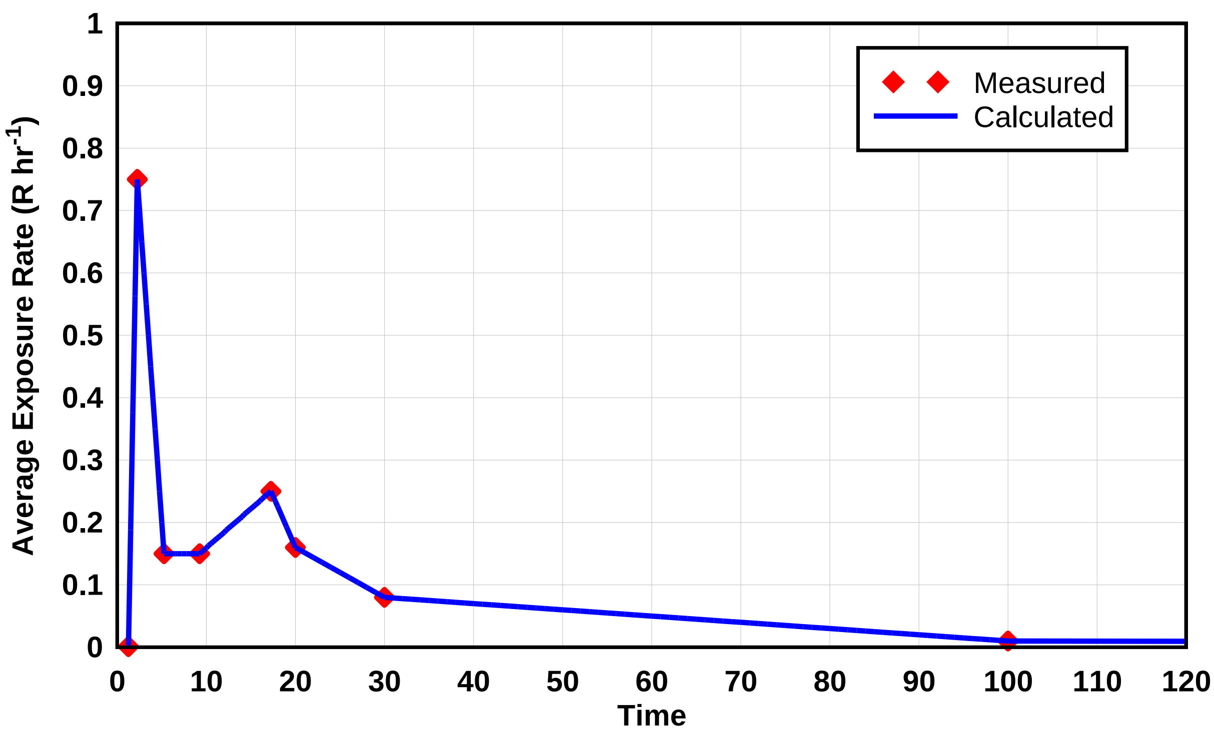

Figure 1. Average Topside Residual Radiation Exposure Rate on USS PHILIP from Shot BRAVO

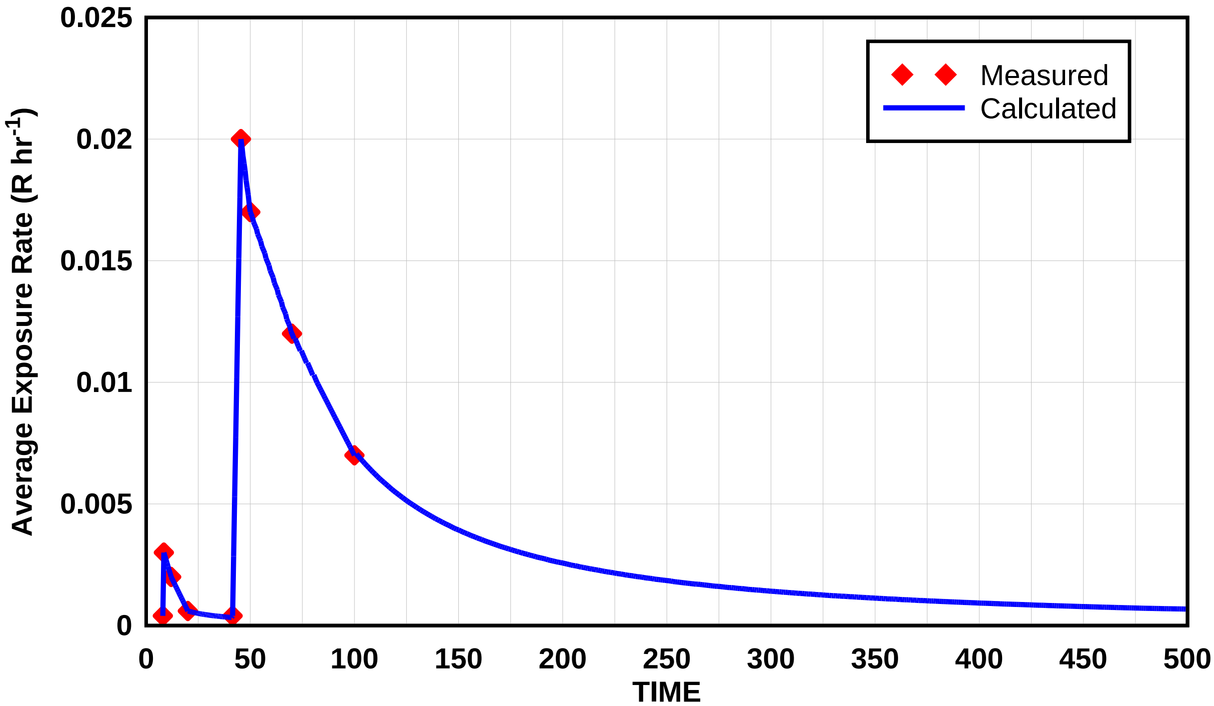

Figure 2. Average Topside Residual Radiation Exposure Rate on USS PHILIP from Shot ROMEO

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided USS PHILIP cohort analysis:

- The period of exposure used is from the onset of BRAVO fallout until one year after the USS PHILIP departed from the PPG (Mar 1, 1954–May 30, 1955).
- The number of hours spent topside is increased to 16 hr day^{-1} from the default 8 hr day^{-1} (DTRA, 2010, ED02).
- A shielding factor of 0.15 (fraction transmitted) for time spent below deck is used (Thomas et al., 1983).
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure Pathways for CASTLE High-Dose Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from deposited fallout during and after Operation CASTLE	USS PHILIP crew members were exposed to fallout from Shots BRAVO and ROMEO while topside and while below deck during the operational period and for one year following the end of Operation CASTLE.	Assumed 16 hr day^{-1} topside instead of 9.6 hr day^{-1}. Assumed a shielding factor of 0.15 instead of ship specific shielding factor of 0.14.
Residual radiation from hull contamination while below deck during and after Operation CASTLE	USS PHILIP crew members were exposed to radiation from accumulated radioactive materials on the underwater hull from Shots BRAVO and ROMEO during the operational period and for one year following the end of Operation CASTLE.	
Residual radiation from contaminated salt water piping and evaporators while below deck during and after Operation CASTLE	USS PHILIP crew members were exposed to radiation from accumulated radioactive materials in the salt water piping and evaporators from Shots BRAVO and ROMEO during the operational period and for one year following the end of Operation CASTLE.	
Residual radiation from deposited fallout while on shore liberty during Operation CASTLE	USS PHILIP crew members were exposed to residual fallout from Shots BRAVO, ROMEO, and KOON during shore liberty periods at Bikini Atoll, and from Shots BRAVO and ROMEO during shore liberty periods at Enewetak Atoll during the operational period of Operation CASTLE.	Assumed shore liberty for 4 hours every 4^{th} day with entire shore liberty time spent outside.
INTERNAL		
Inhalation of resuspended fallout while topside from two fallout episodes	USS PHILIP crew members were subjected to inhalation of resuspended fallout from Shots BRAVO and ROMEO until 100 hr after the time of peak exposure rate.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Used a gamma source modification factor of 4.31 instead of 2.
Inhalation of resuspended fallout during shore liberty periods	USS PHILIP crew members were subjected to inhalation of resuspended fallout from Shots BRAVO, ROMEO, and KOON during shore liberty periods at Bikini Atoll, and from Shots BRAVO and ROMEO during shore liberty periods at Enewetak Atoll during the operational period of Operation CASTLE.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed shore liberty for 4 hours every 4^{th} day with entire shore liberty time spent outside.
Incidental ingestion of contaminated soil/dust during shore liberty periods.	USS PHILIP crew members incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots BRAVO, ROMEO, and KOON during shore liberty periods at Bikini Atoll, and from Shots BRAVO and ROMEO during shore liberty periods at Enewetak Atoll during the operational period of Operation CASTLE.	Assumed shore liberty for 4 hours every 4^{th} day with entire shore liberty time spent outside.

Table 4. Input Parameter Values and Other Values in EPG Scenario Dose Analysis

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Reported}$	CASTLE start date[time]	1 Mar 1954[0645]
$Date_{EndOp}$	CASTLE end date[time]	31 May 1954[2400]
$Date_{Detacked}$	Ship detached date[time]	31 May 1955[2400]
$Date_{Enew1Start}$	Shore liberty at Enewetak Atoll Period 1 start date[time]	1 Mar 1954[0645]
$Date_{Enew1End}$	Shore liberty at Enewetak Atoll Period 1 end date[time]	7 Apr 1954[2400]
$Date_{EnyuStart}$	Shore liberty at Bikini Atoll start date[time]	8 Apr 1954[0000]
$Date_{EnyuEnd}$	Shore liberty at Bikini Atoll end date[time]	25 Apr 1954[2400]
$Date_{Enew2Start}$	Shore liberty at Enewetak Period 2 start date[time]	26 Apr 1954[0000]
$Date_{Enew2End}$	Shore liberty at Enewetak Period 2 end date[time]	31 May 1954[2400]
EXTERNAL DOSE		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
SF	Shielding factor while below deck	0.15 (Thomas et al., 1983)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
$IpeakDet_{BR1}$ $TpeakDet_{BR1}$	Peak exposure rate and time of peak exposure rate on USS PHILIP due to fallout from Shot BRAVO (first episode)	0.750 R hr^{-1} at H+2.25 (Thomas et al., 1984)
$IpeakDet_{BR2}$ $TpeakDet_{BR2}$	Peak exposure rate and time of peak exposure rate on USS PHILIP due to fallout from Shot BRAVO (second episode)	0.25 R hr^{-1} at H+17.25 (Thomas et al., 1984)
$IpeakDet_{RM1}$ $TpeakDet_{RM1}$	Peak exposure rate and time of peak exposure rate on USS PHILIP due to fallout from Shot ROMEO (first episode)	0.003 R hr^{-1} at H+8.5 (Thomas et al., 1984)
$IpeakDet_{RM2}$ $TpeakDet_{RM2}$	Peak exposure rate and time of peak exposure rate on USS PHILIP due to fallout from Shot ROMEO (second episode)	0.02 R hr^{-1} at H+45.5 (Thomas et al., 1984)
$IpeakDet_{BREnew}$ $TpeakDet_{BREnew}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot BRAVO at Enewetak Atoll	0.010 R hr^{-1} at H+16 (Thomas et al., 1984)
$IpeakDet_{RMEnew}$ $TpeakDet_{RMEnew}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO at Enewetak Atoll	0.009 R hr^{-1} at H+77.5 (Thomas et al., 1984)
$IpeakDet_{BREnyu}$ $TpeakDet_{BREnyu}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot BRAVO at Bikini Atoll (Eneu Island)	1.7 R hr^{-1} at H+48 (Thomas et al., 1984)

Table 4. Input Parameter Values and Other Values in EPG Scenario Dose Analysis (cont.)

Parameter	Definition	Value
$IpeakDet_{RMEnyu}$ $TpeakDet_{RMEnyu}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO at Bikini Atoll (Eneu Island)	0.10 R hr^{-1} at H+48 (Thomas et al., 1984)
$IpeakDet_{KNEnyu}$ $TpeakDet_{KNEnyu}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot KOON at Bikini Atoll (Eneu Island)	0.032 R hr^{-1} at H+120 (Thomas et al., 1984)
λ_1	Decay exponent for times less H+3	1.34 (DTRA, 2008, Appendix B-5)
λ_2	Decay exponent for times between H+3 and H+10	1.19 (DTRA, 2008, Appendix B-5)
λ_3	Decay exponent for times between H+10 and H+48	0.82 (DTRA, 2008, Appendix B-5)
λ_4	Decay exponent for times between H+48 and H+480	1.5 (DTRA, 2008, Appendix B-5)
λ_5	Decay exponent for times between H+480 and H+4380	1.2 (DTRA, 2008, Appendix B-5)
λ_6	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-5)
λ_7	Decay exponent for hull contamination and salt water system contamination	1.3 (DTRA, 2008, Appendix B-5)
ShipConDet	Ship contamination exposure rate during Operation CASTLE	Thomas et al., 1984
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for ship-based and shore liberty activities	2.0 m^3 hr^{-1} (Weitz et al., 2009)
$GSMF_{PHILIP}$	Gamma source modification factor for Shot BRAVO exposure rate measurements	4.31 (mean value for the USS PHILIP) (Weitz, 2010)
F_{ts}	Fraction of time spent topside (time exposed to resuspended fallout during Shots BRAVO and ROMEO)	0.67 (= 16/24)
$Frac_{SL}$	Fraction of time spent on shore liberty	4 hr every 4th day 0.0417 = 4/(24 × 4)
K_{Ship}	Resuspension factor for resuspension of fallout from ship surfaces	$K = 10^{-5}$ m^{-1} (DTRA, 2010, SM ID01)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate during shore liberty periods	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density during shore liberty periods	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{Inhfbe} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 μm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the CASTLE high-dose ship-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for CASTLE High-Dose Ship-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	8		23	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.001	0.02	0.009	0.2
Bone Surface	0.5	0.5	5	5
Brain	0.001	0.008	0.009	0.08
Breast	0.001	0.02	0.009	0.2
Stomach Wall	0.001	0.1	0.009	1
Small Intestine Wall	0.001	0.2	0.009	2
Upper Large Intestine Wall	0.001	0.7	0.009	7
Lower Large Intestine Wall	0.001	2	0.009	13
Kidney	0.003	0.03	0.03	0.3
Liver	0.1	0.08	1	0.8
Extra-Thoracic Region	0.005	2	0.05	21
Lung	0.02	3	0.2	24
Muscle	0.001	0.03	0.009	0.2
Pancreas	0.001	0.02	0.009	0.2
Red Marrow	0.03	0.05	0.3	0.5
Spleen	0.001	0.02	0.009	0.2
Testes	0.007	0.01	0.07	0.2
Thymus	0.001	0.02	0.009	0.2
Thyroid	0.001	2	0.009	16
Urinary Bladder Wall	0.001	0.04	0.009	0.4

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 5 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 6. Cancer Cases not recommended for Expedited Processing for CASTLE High-Dose Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Bile Duct	Liver	25
Esophagus	Extra-Thoracic Region	44
Gall Bladder	Liver	25
Liver	Liver	25
Acute Lymphocytic Leukemia	Red Bone Marrow	24
Thyroid	Thyroid	38
Total EPG upper-bound dose below but close to the screening dose		
Acute Myeloid Leukemia	Red Bone Marrow	24
Bone	Bone Surface	33
Stomach	Stomach Wall	24
Colon	Lower Large Intestine Wall	36
Lung	Lung	47
Parathyroid	Thyroid	38

6. References

DNA (Defense Nuclear Agency), 1981. *Operation CASTLE Radiological Safety*. WT-942 (EX), Extracted Version, Defense Nuclear Agency, Washington, DC. April 1.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Martin, E.J., and Rowland, R.H., 1982. *CASTLE Series, 1954.* DNA 6035F, Defense Nuclear Agency, Washington, DC. April 1.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J. and Weitz, R. 1984. *Analysis of Radiation Exposure for Naval Personnel at Operation CASTLE.* DNA-TR-84-6, Defense Nuclear Agency, Washington, DC. February 28.

Thomas, C., Stuart, J., Goetz, J., and Klemm, J., 1983, *Analysis of Radiation Exposure for Naval Personnel at Operation IVY.* DNA TR-82-98, Defense Nuclear Agency, Washington, DC, March 15

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1).* NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure
for Expedited Processing

Operation CASTLE
Low-Dose Ship-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation CASTLE Low-Dose Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation CASTLE Low-Dose Ship-Based Personnel Expedited Processing Group (EPG) consists of approximately 4,000 military personnel who were assigned to U.S. Navy ships during Operation CASTLE (1954) (Martin and Rowland, 1982; DTRA, 2008, Appendix B-5). Although general activities of the crew members of the various ships in this EPG were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure of these participants involving relevant CASTLE shots were similar. Therefore it is reasonable to include most participants assigned to the low-dose (i.e., <2 rem external gamma dose for the entire Operation CASTLE period and received lighter fallout) ship-based personnel during CASTLE in an EPG. The ships participated in a variety of shots during CASTLE. A list of the CASTLE ships is included in Table 1. A list of the transient ships in the PPG during CASTLE is included in Table 2 (Martin and Rowland, 1982).

Table 1. Naval Ships that Participated in Operation CASTLE (Low-Dose Ship-Based Personnel)

Ship	Arrival Date (1954)	Departure Date (1954)	Duty (unit and Task Unit)	Size
USNS FRED C. AINSWORTH (TAP 181)	Feb 24	May 21	7.3.9 Transport Unit	30
USS APACHE (ATF 67)	~Feb 1*	Mar 14	7.3.5 Utility Unit	82
USS BELLE GROVE (LSD 2)	Feb 19	May 14	7.3.9 Transport Unit	338
USS COCOPA (ATF 101)	Feb 13	May 18	7.3.5 Utility Unit	81
USS CURTISS (AV 4)	Jan 24	May 14	7.3.0 Special Devices Unit	708
USS EPPERSON (DDE 719)	Jan 24	May 14	7.3.1 Surface Security Unit	307
USS ESTES (AGC 12)	Feb 6	May 14	7.3.4 Joint Task Force Flagship Unit	647
LST 551	Jan 5	May 16	7.3.9 Special Devices Transport	105
LST-762	Feb 11	May 30	7.3.9 Special Devices Transport	128
LST 825	Feb 11	Mar 2	7.3.9 Special Devices Transport	108

Table 1. Naval Ships that Participated in Operation CASTLE (Low-Dose Ship-Based Personnel) (cont.)

Ship	Arrival Date (1954)	Departure Date (1954)	Duty (unit and Task Unit)	Size
LST 1146	Mar 14	April 5	7.3.9 Special Devices Transport	95
LST 1157	Mar 24	May 13	7.3.7 Landing Ship Dock Element	134
USS MENDER (ARSD 2)	Mar 24	May 12	7.3.5 Utility Unit	64
USS MOLALA (ATF 106)	Feb 6	May 25	7.3.5 Utility Unit	86
USS NICHOLAS (DDE 449)	Jan 24	May 15	7.3.1 Surface Security Unit	273
PC 1546	Feb 20	May 8	7.3.1 Surface Security Unit	60
USS RECLAIMER (ARS 42)	April 7	May 4	7.3.7 Landing Ship Dock Element	94
USS RENSHAW (DDE 499)	Jan 24	May 15	7.3.1 Surface Security Unit	259
USS SHEA (DM 30)	Mar 30	May 8	7.3.7 Landing Ship Dock Element	272
USS SIOUX (ATF 75)	Jan 26	May 18	7.3.5 Utility Unit	86
USS TAWAKONI (ATF 114)	Feb 6	May 8	7.3.5 Utility Unit	81
USS MANATEE (AO 58), USS MISPILLION (AO 105), USS NAMAKAGON (AOG 53), USS NAVASOTA (AO 106)	Various	Various	Fuel Tanker	Various
USS DOUGLAS A. MUNRO (DDE 442), USS EDMONDS (DE 406), LST 975, PC 1141, PC 1145, USS SILVERSTEIN (DE 534)	Various	Various	Search and Rescue	Various
			Total	4,030 +

* Estimated from arrival dates of other ships.

Table 2. Transient Naval Ships that Participated in Operation CASTLE (Low-Dose Ship-Based Personnel)

Ship	Arrival Date (1954)	Departure Date (1954)	Duty (unit and Task Unit)
USS AREQUIPA (AF 31)	May 1	May 8	Cargo
USS DELIVER (ARS 23)	~April 26	~May 14	Cargo
USS DOUGLAS A. MUNRO (DDE 442)	March 1	March 4	Search and Rescue for Australian Canberra Bomber
USS EDMONDS (DE 406)	Feb 24	Mar 2	Search and Rescue for Australian Canberra Bomber
USS GENESEE (AOC 18)	March 17	March 22	Gasoline Tanker
USS KARIN (AF 38)	April 2	April 9	Cargo
USNS LEO (T-AKA 60)	April 22	May 5	Cargo
LST-975	April 28	~May 7	Towing LST-762
USS MANATEE (AO 58)	March 14	April 14	Oiler
USS MERAPI (AF 38)	March 6	~March 11	Cargo
USS MISPILLION (AO 105)	Feb 21	March 4	Oiler
USS NAMAKAGON (AOG 53)	May 10	May 13	Gasoline Tanker
USS NAVASOTA (AO 106)	April 30	May 5	Oiler
PC 1141	Mar 1	Mar 3	Search and Rescue for Australian Canberra Bomber
PC 1145	Feb 27	Mar 3	Search and Rescue for Australian Canberra Bomber
USS SILVERSTEIN (DE 534)	Mar 2	Mar 3	Search and Rescue for Australian Canberra Bomber
USS UNADILLA (ATA 182)	April 8	April 9	Cargo

The following individuals and cohorts are excluded from expedited processing under this EPG:

- Individuals who made shore excursions on Rongelap or Rongerik Atolls.
- Crew member of YAG 39 (USS GEORGE EASTMAN), USS PATAPSCO (AOG 1), or YAG 40 (GRANVILLE S. HALL).

2. Basis of Dose Analysis for Operation CASTLE, Low-Dose Ship-Based Personnel

To estimate EPG doses for all Operation CASTLE Low-Dose Ship-Based Personnel an exposure scenario was developed based on activities of the cohort group that received the highest dose from exposure to external residual radiation and corresponding internal doses. Exposures to initial neutron and gamma radiation are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

This cohort is referred to as the "highest-dose cohort". For this EPG, the activities of the USS ESTES form the basis for the generic highest-dose cohort scenario (DTRA, 2008, Appendix B-5) for two primary reasons:

- This group received the largest external gamma dose from residual radiation for all Operation CASTLE Low-Dose Ship-Based Personnel (DTRA, 2008, Appendix B-5).
- The activities of this group are well-documented and are representative of other Operation CASTLE Low-Dose Ship-Based Personnel.

As explained below, several dose components and assumptions were added to the documented USS ESTES scenario (Martin and Rowland, 1982) to produce EPG doses. The basic scenario of participation and radiation exposure of the USS ESTES is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: USS ESTES Personnel

To estimate bounding doses for all military personnel assigned to low-dose U.S. Navy ships during Operation CASTLE, a generic high-sided exposure scenario was developed based on activities of the crew members of the USS ESTES.

The USS ESTES was the amphibious force command ship that served as the joint task force flag ship in Task Unit 7.3.4, Joint Task Force Flagship Unit, during Operation CASTLE (Martin and Rowland, 1982).

The radiation exposure rates aboard the USS ESTES resulting from two fallout events of Shots BRAVO and ROMEO are listed in Table 3 and shown in Figure 1–Figure 2. These two fallouts were the only ones that deposited on USS ESTES. Based on these exposure rates, decayed to the end of the USS ESTES participation, crew members accrued external doses from deposited fallout while topside and while below deck. They are assumed to have spent all day every day on board the ship during the period Mar 1–May 30, 1954 except for shore liberty. They also received internal doses while topside from inhalation of resuspended fallout for the first 100 hours after each fallout episode. (DTRA, 2008, Appendix B-5)

Table 3. Peak Radiation Exposure Rates on USS ESTES during Operation CASTLE

Shot	Shot Date (1954) (Time)	Peak Exposure Rate (R hr^{-1})	Time of Peak Exposure Rate (H+hr)
BRAVO	Mar 1 (0645)	0.400	16
ROMEO	Mar 27 (0630)	0.012	42

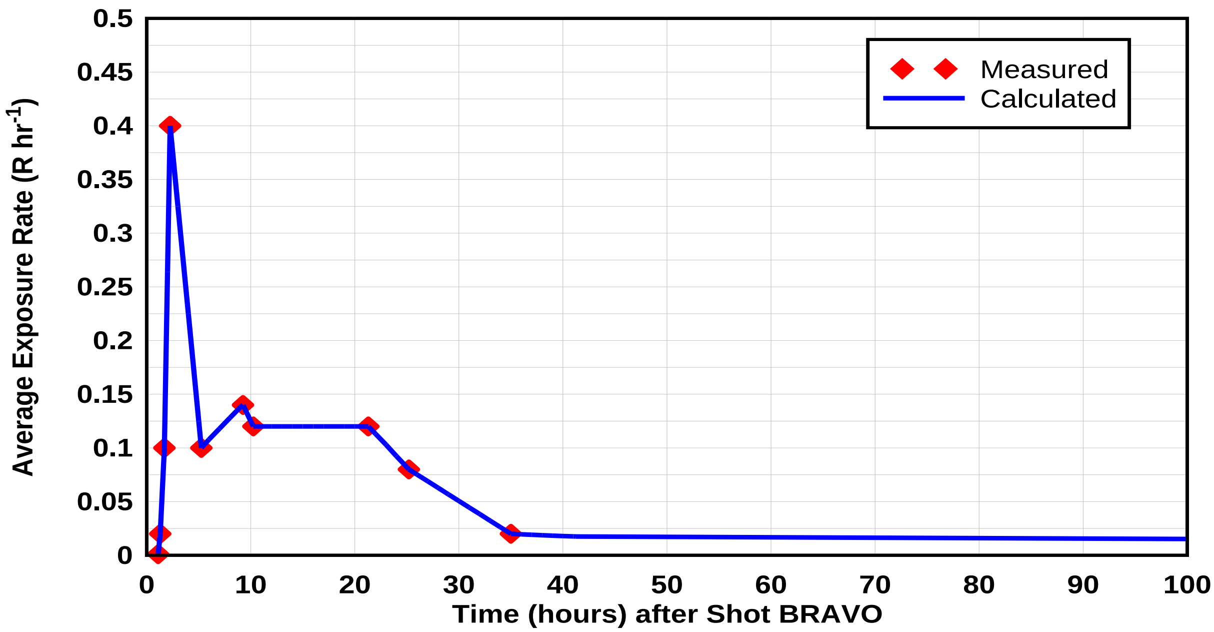

Figure 1. Average Topside Residual Radiation Exposure Rates on USS ESTES from Shot BRAVO

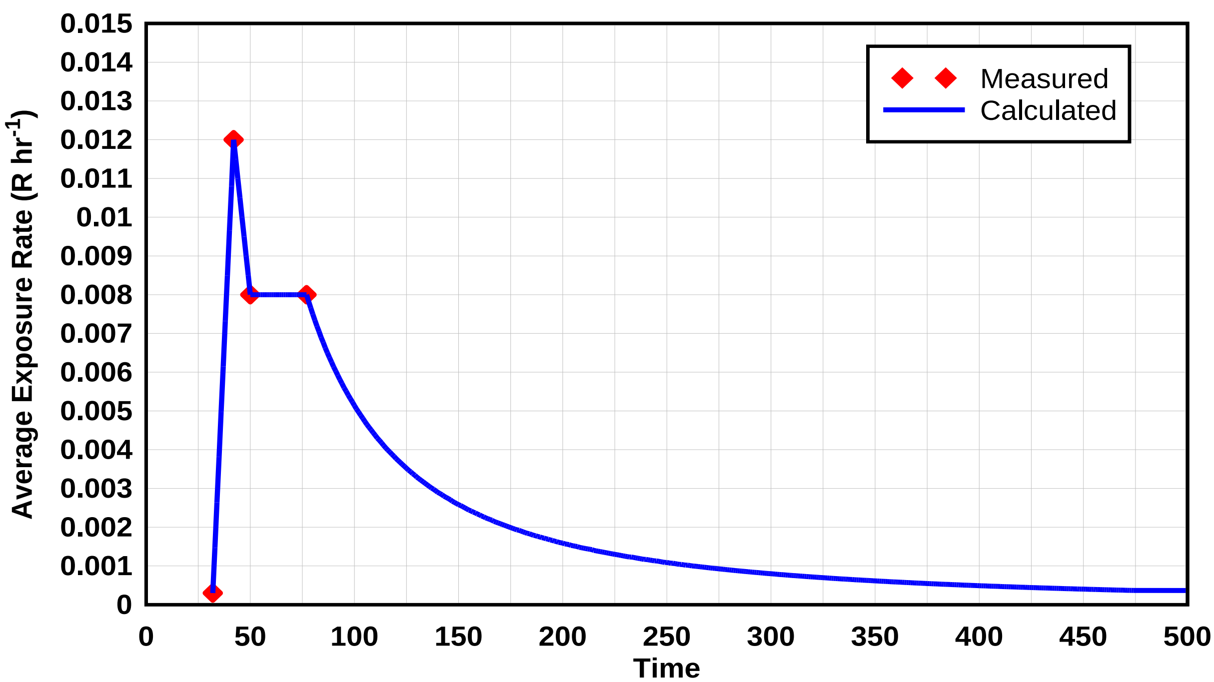

Figure 2. Average Topside Residual Radiation Exposure Rate on USS ESTES from Shot ROMEO

The USS ESTES crew also accrued external doses from three other sources: accumulated radioactive materials on its underwater hull; accumulated radioactive materials in its salt water piping and evaporators; and radioactive fallout in beach and shore areas during shore liberty. Although partially attenuated by the hull and piping structures, the gamma radiation emitted by these hull and salt water system contaminants was a source of exposure to crewmembers in below-deck spaces. Crew members were exposure to radioactive fallout while on Bikini and Enewetak Atoll during shore liberty (DTRA, 2008, Appendix B-5).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided USS ESTES cohort analysis. These are described below.

- The period of assignment to USS ESTES is assumed to include the entire potential period of exposure to fallout while USS ESTES was in the PPG. The assignment period used is from the onset of BRAVO fallout until one year after the departed from the PPG (Mar 1–May 30) (DTRA, 2008, Appendix B-5).
- The number of hours spent topside is increased from 9.6 to 16 hr day^{-1}.
- The highest shielding factor of 0.15 (fraction transmitted) for time spent below deck is used (Thomas et al., 1983).
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 4. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 5.

Table 4. Exposure Pathways for CASTLE Low-Dose Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from deposited fallout during and after Operation CASTLE	USS ESTES crew members were exposed to fallout from Shots BRAVO and ROMEO while topside during the operational period and for one year following the end of Operation CASTLE.	Assumed 16 hr day^{-1} topside instead of 9.6 r day^{-1}. Shielding factor (fraction transmitted) was increased to 0.15 from 0.09.
Residual radiation from hull contamination while below deck during and after Operation CASTLE	USS ESTES crew members were exposed to radiation from accumulated radioactive materials on the underwater hull during the operational period and for one year following the end of Operation CASTLE.	
Residual radiation from salt water piping and evaporator contamination while below deck during and after Operation CASTLE	USS ESTES crew members were exposed to radiation from accumulated radioactive materials on the underwater hull and in salt water piping and evaporators during the operational period and for one year following the end of Operation CASTLE.	
Residual radiation from deposited fallout while on shore liberty during Operation CASTLE	USS ESTES crew members were exposed to fallout from Shots BRAVO, ROMEO, and KOON during shore liberty periods at Bikini Atoll, and from Shots BRAVO and ROMEO during shore liberty periods at Enewetak Atoll during the operational period of Operation CASTLE.	Assumed exposure rate was the highest for any part of the island during shore liberty island.
INTERNAL		
Inhalation of resuspended fallout while topside from three fallout episodes	USS ESTES crew members were subjected to inhalation of resuspended fallout from Shots BRAVO, ROMEO, and YANKEE until 100 hr after the time of peak exposure rate.	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during shore liberty periods	USS ESTES crew members were subjected to inhalation of resuspended fallout from Shots BRAVO, ROMEO, and KOON during shore liberty periods at Bikini Atoll, and from Shots BRAVO and ROMEO during shore liberty periods at Enewetak Atoll during the operational period of Operation CASTLE.	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust during shore liberty periods.	USS ESTES crew members incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots BRAVO, ROMEO, and KOON during shore liberty periods at Bikini Atoll, and from Shots BRAVO and ROMEO during shore liberty periods at Enewetak Atoll during the operational period of Operation CASTLE.	

Table 5. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Reported}$	CASTLE start date[time]	1 Mar 1954[0645]
$Date_{EndOp}$	CASTLE end date[time]	31 May 1954[2400]
$Date_{Detacked}$	Ship detached date[time]	31 May 1955[2400]
$Date_{Enew1Start}$	Shore liberty at Enewetak Atoll Period 1 start date[time]	1 Mar 1954[0645]
$Date_{Enew1End}$	Shore liberty at Enewetak Atoll Period 1 end date[time]	7 Apr 1954[2400]
$Date_{EnyuStart}$	Shore liberty at Bikini Atoll start date[time]	8 Apr 1954[0000]
$Date_{EnyuEnd}$	Shore liberty at Bikini Atoll end date[time]	25 Apr 1954[2400]
$Date_{Enew2Start}$	Shore liberty at Enewetak Period 2 start date[time]	26 Apr 1954[0000]
$Date_{Enew2End}$	Shore liberty at Enewetak Period 2 end date[time]	31 May 1954[2400]
EXTERNAL DOSE		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
SF	Shielding factor (fraction transmitted) while below deck	0.15 (Thomas et al., 1983)
$IpeakDet_{BR}$ $TpeakDet_{BR}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot BRAVO (also applies to shore liberty at Enewetak Atoll)	0.40 R hr^{-1} at H+2.25 (Thomas et al., 1984)
$IpeakDet_{RM1}$ $TpeakDet_{RM1}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO (first episode)	0.012 R hr^{-1} at H+42 (Thomas et al., 1984)
$IpeakDet_{RM2}$ $TpeakDet_{RM2}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO (second episode) (also applies to shore liberty at Enewetak Atoll)	0.008 R hr^{-1} at H+77 (Thomas et al., 1984)
$IpeakDet_{BREnyu}$ $TpeakDet_{BREnyu}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot BRAVO at Bikini Atoll (Enyu Island)	1.7 R hr^{-1} at H+48 (Thomas et al., 1984)
$IpeakDet_{RMEnyu}$ $TpeakDet_{RMEnyu}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO at Bikini Atoll (Enyu Island)	0.100 R hr^{-1} at H+48 (Thomas et al., 1984)
$IpeakDet_{KNEnyu}$ $TpeakDet_{KNEnyu}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot KOON at Bikini Atoll (Enyu Island)	0.032 R hr^{-1} at H+120 (Thomas et al., 1984)

Table 5. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
λ_1	Decay exponent for times less H+3	1.34 (DTRA, 2008, Appendix B-5)
λ_2	Decay exponent for times between H+3 and H+10	1.19 (DTRA, 2008, Appendix B-5)
λ_3	Decay exponent for times between H+10 and H+48	0.82 (DTRA, 2008, Appendix B-5)
λ_4	Decay exponent for times between H+48 and H+480	1.5 (DTRA, 2008, Appendix B-5)
λ_5	Decay exponent for times between H+480 and H+4380	1.2 (DTRA, 2008, , Appendix B-5)
λ_6	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-5)
λ_7	Decay exponent for hull contamination and salt water system contamination	1.3 (DTRA, 2008, Appendix B-5)
ShipConDet	Ship contamination exposure rate during Operation CASTLE	Thomas et al., 1984
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for ship-based activities and shore liberty	2.0 m^3 hr^{-1} (Weitz et al., 2009)
$GSMF_{ESTES}$	Gamma source modification factor for Shot BRAVO and ROMEO exposure rate measurements	2.95 (mean value for the USS ESTES) (Weitz, 2010)
$GSMF_{land}$	Gamma source modification factor based on the Enewetak Island where the exposure rate measurements were made.	1.0 (DTRA, 2008, Appendix B-5)
F_{ts}	Fraction of time spent topside (time exposed to resuspended fallout during Shots BRAVO, ROMEO, and KOON)	0.67 (= 16/24)
$Frac_{SL}$	Fraction of time spent on shore liberty	4 hr every 4th day 0.0417 = 4/(24 × 4)
K_{Ship}	Resuspension factor for resuspension of fallout from ship surfaces	$K = 10^{-5}$ (DTRA, 2010, SM ID01)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate during shore liberty periods	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density during shore liberty periods	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{Inhfbe} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the CASTLE low-dose ship-based personnel are summarized in Table 6. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 6 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 6. External and Internal Doses and Upper Bounds for CASTLE Low-Dose Ship-Based Personnel

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	4		12	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.008	0.02	0.08
Bone Surface	0.7	0.5	7	5
Brain	0.002	0.004	0.02	0.04
Breast	0.002	0.007	0.02	0.07
Stomach Wall	0.002	0.04	0.02	0.4
Small Intestine Wall	0.002	0.07	0.02	0.7
Upper Large Intestine Wall	0.002	0.3	0.02	3
Lower Large Intestine Wall	0.002	0.6	0.02	6
Kidney	0.003	0.02	0.03	0.2
Liver	0.2	0.09	2	0.9
Extra-Thoracic Region	0.007	0.8	0.07	8
Lung	0.02	2	0.2	12
Muscle	0.002	0.007	0.02	0.07
Pancreas	0.002	0.008	0.02	0.08
Red Marrow	0.04	0.04	0.4	0.4
Spleen	0.002	0.007	0.02	0.07
Testes	0.01	0.008	0.1	0.08
Thymus	0.002	0.009	0.02	0.09
Thyroid	0.002	0.7	0.02	7
Urinary Bladder Wall	0.002	0.02	0.02	0.2

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 6 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 7. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 7. Cancer Cases not Recommended for Expedited Processing for CASTLE Low-Dose Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	9
Liver	Liver	15
Total EPG upper-bound dose below but close to the screening dose		
Gall Bladder	Liver	15
Bile Duct	Liver	15

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Martin, E.J., and Rowland, R.H., 1982. *CASTLE Series, 1954.* DNA 6035F, Defense Nuclear Agency, Washington, DC. April 1.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J. and Weitz, R. 1984. *Analysis of Radiation Exposure for Naval Personnel at Operation CASTLE*. DNA-TR-84-6, Defense Nuclear Agency, Washington, DC. February 28.

Thomas, C., Stuart, J., Goetz, J., and Klemm, J., 1983, *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*. DNA TR-82-98, Defense Nuclear Agency, Washington, DC, March 15

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1)*. NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation CASTLE Land-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation CASTLE Land-Based Personnel

1. Description of the Expedited Processing Group

The Operation CASTLE Land-Based Personnel Expedited Processing Group (EPG) consists of approximately 3,200 military personnel who were assigned to support Operation CASTLE (Martin and Rowland, 1982; DTRA, 2008). These personnel were stationed on the residence islands of Enewetak Atoll, consisting of Enewetak, Parry, and Japtan Islands, along with Eneu Island, Bikini Atoll, and Kwajalein Atoll along with the weather stations on Kusaie Island and Ponape Island.

The land-based residents had a wide range of assignments but their activities would have resulted in exposures to residual radiations that were similar. Furthermore, the sources of radiation exposure and activities resulting in exposure of these residents from relevant Operation CASTLE shots were similar. Therefore it is reasonable to include all island residents in a single EPG.

The CASTLE test series is described in Martin and Rowland (1982). Specific land-based units are listed in Table 1.

The following individuals are excluded from expedited processing under this EPG:

- Individuals who visited or resided on Rongelap or Rongerik Atolls after Shot BRAVO.

2. Basis of Dose Analysis for Operation CASTLE Land-Based Personnel

To estimate EPG doses for all CASTLE Land-Based personnel, an exposure scenario was developed based on activities of the island residents group that received the highest dose from exposure to external residual radiation and corresponding internal doses. This cohort is referred to as the "highest-dose cohort." Exposures to initial neutron and gamma radiation are not taken into consideration when selecting a "highest-dose cohort" because these activities are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of service members assigned to the 7126th Army Unit while resident on Enewetak Island form the basis for the generic highest-dose cohort scenario for four primary reasons:

- This group was the largest single cohort that was in residence on Enewetak Atoll.
- The group was in residence at Enewetak Atoll for the entire time of Operation CASTLE.
- Most of the subunits of the 7126th Army Unit were not involved in Radsafe activities such as monitoring or decontamination.
- The Enewetak island residents were not evacuated during any shot nor took special precautions.

Table 1. Land-Based Units during Operation CASTLE*

Unit	Size
Headquarters, Joint Task Force 7	3
Task Group 7.1 (Scientific) Army Air Force	150 140
7126th Army Unit	1294
8600th Anti-Aircraft Artillery Unit	35
Criminal Investigation Division and Counter-Intelligence Corps Unit	8
Naval Patrol Plane Unit to include VP-29, NAS-Kwajalein, and VR-7	260
Enewetak Harbor Element Boat Pool and Underwater Detection	125
Bikini Harbor Element Boat Pool	200
97th Bombardment Wing to include the 341st Bombardment Squadron, Biggs Air Force Base (ARB), Texas	5
7th bombardment Wing to include the 9th Bombardment Squadron, the 436th Bombardment Squadron, and the 11th Bombardment Wings, Carswell AFB	47
77th Strategic Reconnaissance Squadron, Ellsworth AFB	25
4930th Test Support Group to include the 4931st Test Support Squadron, the 4932nd Test Support Squadron, the 50th Air Transport Squadron, the 1500th Air Transport Squadron, and the 1500-3 Air Base Wing, Enewetak Island	170
Air Defense Command Liaison Officers	15
1901st Airways and Air Communication Service Detachment, Hamilton AFB	2
47th, 49th, and 51st Air Transport Squadrons; 57th Strategic Weather Squadron; HQ, Test Services Unit (Provisional); and Document Photo Element, Hickam AFB	192
HQ, Special Weapons Center; 4926th Test Squadron, 4932nd Test Support Squadron, Kirtland AFB	131
Lockout Mountain Air Force Station	2
57th strategic Reconnaissance Squadron, March AFB	3
Air University, Maxwell AFB	2
6th Weather Reconnaissance Squadron, Team 101, McClellan AFB	8
6th Weather Squadron, Tinker AFB	43
1960th Airways and Air Communication Service, Travis AFB	3
1298th Air Transport Squadron, Washington, DC	1
Others	~10
Total	2,590

* Martin and Rowland (1982)

As explained below, several dose components and assumptions were added to the documented 7126th Army Unit scenario to produce the EPG doses. The basic scenario of participation and radiation exposure of the 7126th Army Unit is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: 7126th Army Unit

To estimate EPG doses for all military personnel assigned to the 7126th Army Unit during CASTLE, a generic high-sided exposure scenario was develop based upon activates of the 7126th Army Unit. Approximately 1300 members of the Army were assigned to the 7126th Army Unit during CASTLE. Most service members assigned to the 7126th Army Unit arrived before January 1, 1954 and stayed until the end of the Operation on May 31, 1954. Members of the 7126th Army Unit lived in tents or barracks on Enewetak Atoll and had their meals in indoor dining facilities. Table 2 lists the fallout events on Enewetak Atoll during Operation CASTLE. The calculated exposure rates due to each descending fallout event are included in Figures 1 to 3 (DTRA, 2008, Appendix B-5; Martin and Rowland, 1982).

Table 2. Fallout on Enewetak Atoll during CASTLE

CASTLE Shot	SHOT Date/Time (1954)	Peak Exposure Rate Measured on Enewetak Atoll (R hr^{-1})	Time After Shot (hr)
BRAVO	Mar 1 at 0645	0.010	16
ROMEO (first fallout episode)	Mar 27 at 0630	0.003	14.5
ROMEO (second fallout episode)	“	0.009	77.5
NECTAR	May 14 at 0630	0.002	14.7

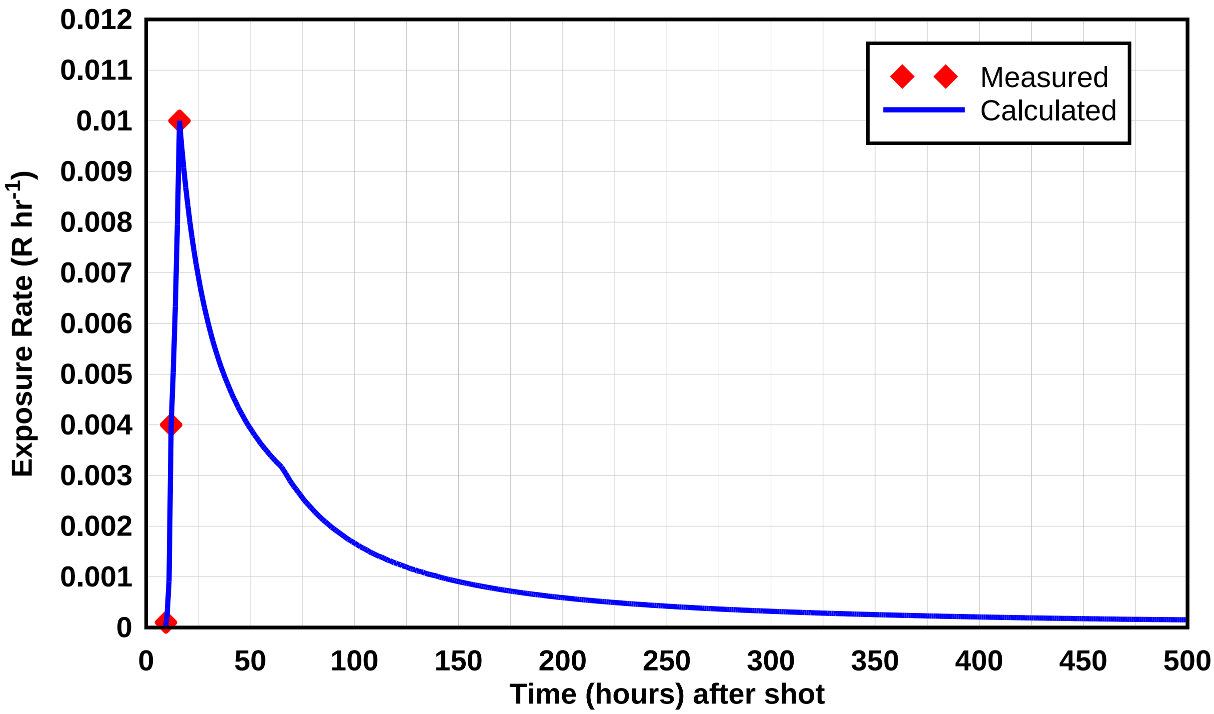

Figure 1. Residual Radiation Exposure Rate on Enewetak Atoll from Shot BRAVO

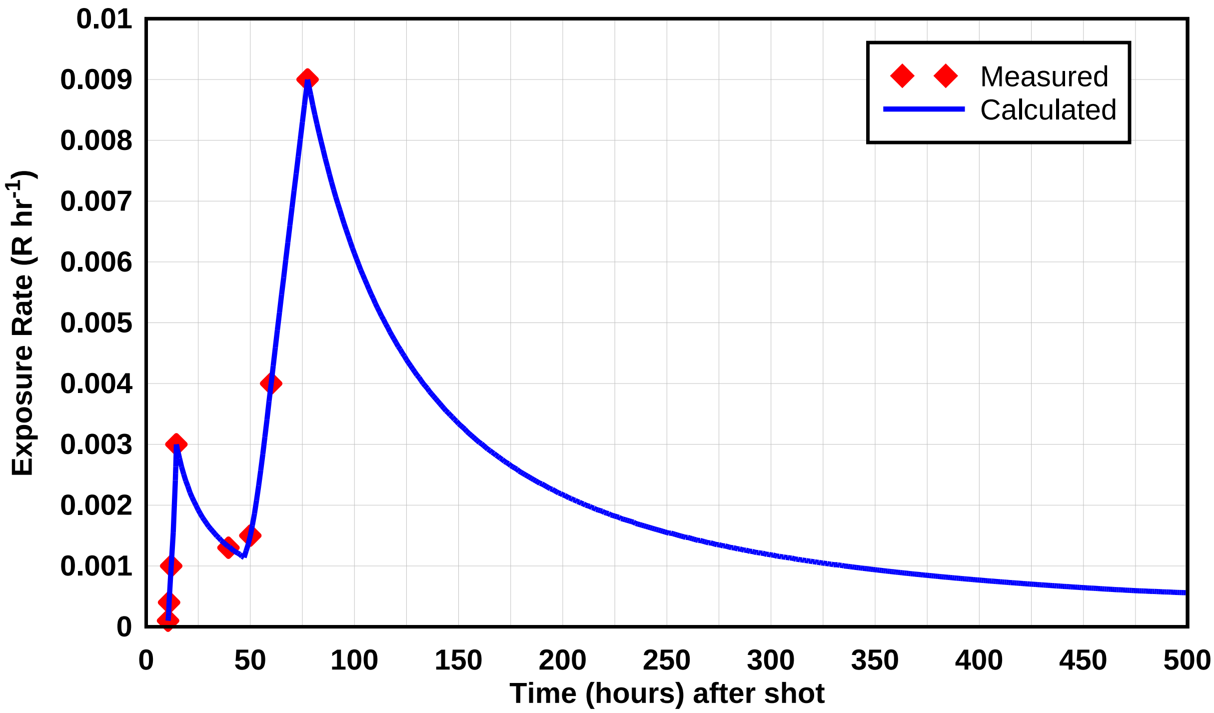

Figure 2. Residual Radiation Exposure Rate on Enewetak Atoll from Shot ROMEO

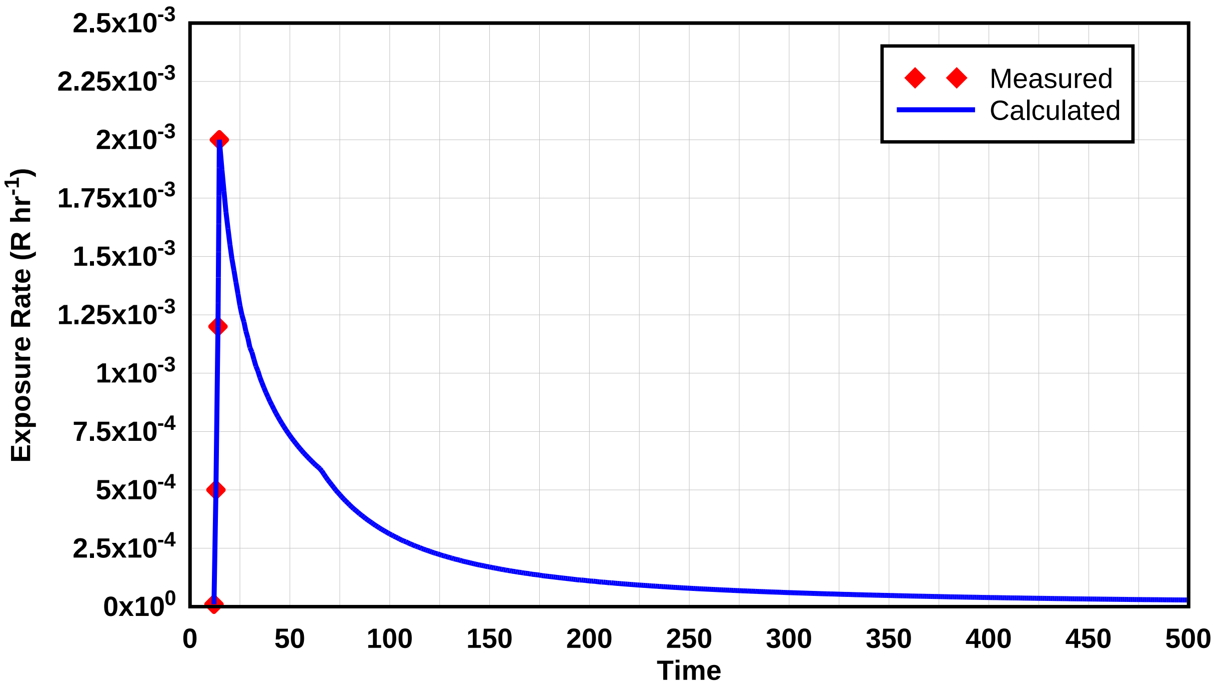

Figure 3. Residual Radiation Exposure Rate on Enewetak Atoll from Shot NECTAR

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions are added to the highest-sided 7126th Army Unit cohort analysis:

- The period of assignment to Enewetak is assumed to be from December 1, 1953 to May 31, 1955.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1} assuming that 8 hours were spent indoors for sleeping, cleaning and eating (DTRA, 2010, SM ED02).
- Although personnel spend their time indoors in either a tent or a metal building, it is assumed that they spent 100 percent of this time in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The island residents is assumed to be outdoors during descending fallout and the fallout was considered light enough so that daily duty routines were not altered (Thomas et al., 1984).
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure Pathways for CASTLE Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from fallout from previous operations' shots	7126th Army Unit personnel were exposed to fallout from Operations GREENHOUSE and IVY shots for three months prior to the start of Operation CASTLE (December 1, 1953).	Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside. Used the lowest protection factor while indoors (1.5 for tents).
Residual radiation from fallout deposited on the residence islands of Enewetak Atoll	7126th Army Unit personnel were exposed to fallout from Shots BRAVO, ROMEO, and NECTAR during the operational period and for one year following the end of Operation CASTLE.	Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside. Used the lowest protection factor while indoors (1.5 for tents).
INTERNAL		
Inhalation of descending fallout from three fallout episodes	7126th Army Unit personnel were subjected to descending fallout from Shots BRAVO, ROMEO, and NECTAR.	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout from previous operations' shots	7126th Army Unit personnel were subjected to inhalation of resuspended fallout from Operations GREENHOUSE and IVY shots for three months prior to the start of Operation CASTLE (December 1, 1953).	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside.
Inhalation of resuspended fallout from current operation's shots	7126th Army Unit personnel were subjected to inhalation of resuspended fallout from Shots BRAVO, ROMEO, and NECTAR during the period March 1, 1954 until the island residents left the Atoll, assumed to be one year after the end of Operation CASTLE (May 31, 1955).	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside. Used the lowest protection factor while indoors (1.5 for tents).
Incidental ingestion of contaminated soil/dust from fallout from previous operations' shots	7126th Army Unit personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Operations GREENHOUSE and IVY shots for three months prior to the start of Operation CASTLE (December 1, 1953).	
Incidental ingestion of contaminated soil/dust from fallout from current operation's shots	7126th Army Unit personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots BRAVO, ROMEO, and NECTAR from March 1, 1954 until departure from Enewetak Atoll, assumed to be one year after the end of Operation CASTLE (May 31, 1955).	

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrive}$-	Enewetak arrival date	1 Dec 1953
$Date_{StartOp}$	CASTLE start date[time]	1 Mar 1954[0645]
$Date_{EndOp}$	CASTLE end date[time]	31 May 1954[2400]
$Date_{Departed}$	Enewetak departure date[time]	31 May 1955[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Atoll	0.67 (= 16/24)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
PF_t	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2008, Appendix B-5)
$IpeakDet_{BR}$ $TpeakDet_{BR}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot BRAVO	0.010 R hr^{-1} at H+16 (DTRA, 2008, Appendix B-5)
$IpeakDet_{RM1}$ $TpeakDet_{RM1}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO (first episode)	0.003 R hr^{-1} at H+14.5 (DTRA, 2008, Appendix B-5)
$IpeakDet_{RM2}$ $TpeakDet_{RM2}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO (second episode)	0.009 R hr^{-1} at H+77.5 (DTRA, 2008, Appendix B-5)
$IpeakDet_{NR}$ $TpeakDet_{NR}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot NECTAR	0.002 R hr^{-1} at H+14.7 (DTRA, 2008, Appendix B-5)
λ_1	Decay exponent for times less H+3	1.34 (DTRA, 2008, , Appendix B-5)
λ_2	Decay exponent for times between H+3 and H+10	1.19 (DTRA, 2008, , Appendix B-5)
λ_3	Decay exponent for times between H+10 and H+48	0.82 (DTRA, 2008, , Appendix B-5)
λ_4	Decay exponent for times between H+48 and H+480	1.5 (DTRA, 2008, , Appendix B-5)
λ_5	Decay exponent for times between H+480 and H+4380	1.2 (DTRA, 2008, , Appendix B-5)
λ_6	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, , Appendix B-5)
$DoseDet_{Pre}$	External gamma dose due to fallout from Operations GREENHOUSE and IVY residual radiation	0.009 rem (Mason, 2009)

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InFBE} DCF_{Inhdes} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 μm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)
$ResInh_{Pre}$ $IncIng_{Pre}$	Internal doses due to fallout from Operations GREENHOUSE and IVY residual radiation	See (DTRA, 2009b) for a list of organ doses

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the CASTLE land-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

The upper-bound doses in Table 5 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. External and Internal Doses and Upper Bounds for CASTLE Land-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	2		5	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.01	0.02	0.1
Bone Surface	0.7	0.5	7	5
Brain	0.002	0.005	0.02	0.05
Breast	0.002	0.008	0.02	0.08
Stomach Wall	0.002	0.05	0.02	0.5
Small Intestine Wall	0.002	0.09	0.02	0.9
Upper Large Intestine Wall	0.002	0.4	0.02	4
Lower Large Intestine Wall	0.002	0.8	0.02	7
Kidney	0.003	0.02	0.03	0.2
Liver	0.2	0.09	2	0.9
Extra-Thoracic Region	0.007	1	0.07	11
Lung	0.02	2	0.2	15
Muscle	0.002	0.008	0.02	0.08
Pancreas	0.002	0.009	0.02	0.09
Red Marrow	0.04	0.04	0.4	0.4
Spleen	0.002	0.008	0.02	0.08
Testes	0.01	0.009	0.1	0.08
Thymus	0.002	0.01	0.02	0.1
Thyroid	0.002	0.8	0.02	8
Urinary Bladder Wall	0.002	0.02	0.02	0.2

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

Table 6. Cancer Cases not Recommended for Expedited Processing for CASTLE Land-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	13
Total EPG upper-bound dose below but close to the screening dose		
Liver	Liver	8

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations*. NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 3

Martin, E.J., and Rowland, R.H., 1982. *CASTLE Series, 1954*. DNA 6035F, Defense Nuclear Agency, Washington, DC. April 1.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J. and Weitz, R. 1984. *Analysis of Radiation Exposure for Naval Personnel at Operation CASTLE*. DNA-TR-84-6, Defense Nuclear Agency, Washington, DC. February 28.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Analysis of Radiation Exposure for Expedited Processing

Operation WIGWAM Ship-Based Personnel

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Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation WIGWAM Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation WIGWAM Ship-Based Personnel Expedited Processing Group (EPG) consists of approximately 6,200 military personnel who were assigned to U.S. Navy ships during Operation WIGWAM (1955) (Weary et al., 1981; DTRA, 2008, Appendix B-6). Although general activities of the crew members of the various ships were different, activities that resulted in exposure residual radiation were similar. Furthermore, the sources of radiation and activities resulting in exposure of participants involving a single test were similar. Therefore it is reasonable to include most participants during Operation WIGWAM into a single EPG.

Operation WIGWAM is described in Weary et al. (1981). A list of the ships at WIGWAM is included in Table 1 (Weary et al., 1981).

U.S. Navy Ships involved in WIGWAM experienced fallout on deck and contamination on deck, on the hull, and in the salt water systems from only one shot. In addition, some of the ships involved in Operation WIGWAM experienced radioactive hull contamination and shine from radioactive material floating in the water near surface zero if the ships entered the areas of contaminated ocean water (Weary et al., 1981).

The following individuals are excluded from expedited processing under this EPG:

- Individual who participated in large scale decontamination.

Ship crews involved in small scale ship decontamination are included in the EPG. Small scale decontamination includes salt-water wash down and hand scrubbing with freshwater and detergent (SAIC, 1981).

2. Basis of Dose Analysis for WIGWAM Ship-Based Personnel

To estimate EPG doses for all WIGWAM ships crews, an exposure scenario was developed based on activities of the cohort group that received one of the highest doses from exposure to external residual radiation based upon film badge results. This cohort is referred to as the "highest-dose cohort". Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

Table 1. U.S. Navy Ships that Participated in Operation WIGWAM

Ship	Duty (unit and Task Unit)	Size
Motor Vessel (M/V) SPENCER F. BAIRD*	7.3.1.8 Oceanographic Support	16 U.S. Navy Personnel
USS BLUE ((DD-744)	7.3.3 Surface Patrol	266
USS BOLSTER (ARS-38)	7.3.4.3 Towing and Savage	91
USS BUTTERNUT (AN-9)	7.3.4.3 Towing and Savage	42
USS CHANTICLEER (ASR-7)	7.3.4.3 Towing and Savage	96
USS COMSTOCK (LSD-19)	7.4.3.1 Transport	241
USS CREE (ATF-84)	7.3.4.3 Towing and Savage	68
USS ALFRED D. CUNNINGHAM (DD-752)	7.3.3 Surface Patrol	268
USS CURTISS (AV-4)	7.3.0 Flagship	573
USS FRANK E. EVANS (DD-754)	7.3.3 Surface Patrol	269
USS FORT MARION (LSD-22)	7.4.3.1 Transport	279
USS GEORGE EASTMAN (YAG-39)	7.1.3.7 Radiological Support	48
USS GRANVILLE S. HALL (YAG-40)	7.1.3.7 Radiological Support	48
USS HITCHITI (ATF-103)	7.3.4.3 Towing and Savage	76
M/V HORIZON	7.3.1.8 Oceanographic Support	18 U.S. Navy Personnel
USS HARRY E. HUBBARD (DD-748)	7.3.3 Surface Patrol	258
USS MCKEAN (DDR-784)	7.3.3 Surface Patrol	256
USS MARION COUNTY (LST-975)	7.4.3.1 Transport	100
USS MOCTOBI (ATF-105)	7.3.4.3 Towing and Savage	69
USS MOLALA (ATF-106)	7.1.3.7 Radiological Support	76
USS MORGAN COUNTY (LST-1048)	7.4.3.1 Transport	96
USS MOUNT MCKINLEY (AGC-7)	7.3.0 Flagship	552
USS O'BRIEN (DD-725)	7.3.3 Surface Patrol	285
M/V PAOLINA*	7.3.1.8 Oceanographic Support	5 U.S. Navy Personnel
USS RECLAIMER (ARS-42)	7.3.4.3 Towing and Savage	78
USS ERNEST G. SMALL (DDR-838)	7.3.3 Surface Patrol	265
USS TAWASA (ATF-92)	7.3.4.3 Towing and Savage	73
M/V T-BOAT	7.3.1.8 Oceanographic Support	10 U.S. Navy Personnel
USS WALKE (DD-723)	7.3.3 Surface Patrol	261
USS WRIGHT (CVL-49)	7.3.2 Carrier Air Support	974 plus 93 in air units
	Total	~ 6,080

* The crews of ships using the M/V designation were generally civilians.

For this EPG, the activities of the USS CHANTICLEER form the basis for the generic highest-dose cohort scenario (DTRA, 2008, Appendix B-6) for two primary reasons:

- USS CHANTICLEER crew members received, on average, the largest external gamma dose from residual radiation for all Operation WIGWAM ship-based personnel. Eighty-one of the 96 personnel on USS CHANTICLEER received a dose above 0.1 rem (Weary et al., 1981). Personnel doses are from film badge dosimetry that includes most crewmembers.
- The activities of this group are well-documented and are representative of other Operation WIGWAM Shipboard Personnel.

As explained below, several dose components and assumptions were added to the documented USS CHANTICLEER scenario (Weary et al., 1981) to produce EPG doses. The basic USS CHANTICLEER crew member scenario is described directly in Section 3, followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: USS CHANTICLEER Crew Members

To estimate EPG doses for all military personnel assigned to U.S. Navy ships during Operation WIGWAM, a generic exposure scenario was developed based on activities of the U.S. Navy ship crew members of the USS CHANTICLEER. The crew members of the USS CHANTICLEER received the highest average external dose of any ship crew at Operation WIGWAM (DTRA, 2008, Appendix B-6).

The USS CHANTICLEER was a submarine rescue ship assigned to the Towing and Salvage Unit (Task Unit 7.3.4.3). The USS CHANTICLEER performed test support operations to include recovering experimentation and salvaging portions of the test array involved in the shot. The USS CHANTICLEER had to enter into ocean waters with radioactive contamination (Weary et al., 1981). The USS CHANTICLEER cohort exposure scenario is described below, followed by a description of the additional dose factors and assumptions.

At the time of the shot at 1300 hours, May 14, 1955, USS CHANTICLEER was upwind of ground zero and did not receive any descending fallout. Only two ships, the USS GEORGE EASTMAN and USS GRANVILLE S. HALL were downwind of the shot and received descending fallout. However, the ships that were downwind had all of their crews below deck in shielded rooms (DTRA, 2008, Appendix B-6; Weary et al., 1981). Sixteen hours after the detonation, the USS CHANTICLEER entered an area of radioactive contamination during recovery and salvage operations. Twenty three (23) hours after detonation, USS CHANTICLEER left the area of contaminated water but realized that the deck has been contaminated by contaminated spray and mist. Decontamination was then conducted that lowered the exposure rates by about 60%. (SAIC, 1981)

The USS CHANTICLEER's crew also accrued external doses from accumulated radioactive materials on its underwater hull, from contamination in the salt water piping, and from shine due to radioactive contamination in the ocean water. Although partially attenuated by the hull and piping structures, the gamma radiation emitted by these hull and salt water system contaminants was a source of exposure to crewmembers in below-deck spaces. The engine room had a residual exposure rate of 0.015 R hr^{-1} and the engine cooling-water discharge line had an exposure rate of 0.12 R hr^{-1}. Crewmen who were topside when the ship operated in contaminated water were exposed to gamma radiation emitted directly from the contaminants in the water. A shine exposure rate of 0.095 R hr^{-1} was reported. The shine was assumed to be part of the external exposure rate measured topside. After decontamination, the engine room exposure rate dropped to 0.004 R hr^{-1} and the cooling-water discharge line had an exposure rate of 0.06 R hr^{-1} (SAIC, 1981; DTRA, 2008, Appendix B-6).

The crew of USS CHANTICLEER was issued film badges for Operation WIGWAM. Of the 100 individuals aboard, 96 individuals have an exposure record. The recorded mean exposure reading for the 96 is 0.104 rem and the mode was 0.13 rem (SAIC, 1981; DTRA, 2008, Appendix B-6).

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the already high-sided USS CHANTICLEER cohort analysis:

- The individual external dose is reconstructed using an average positive film badge result of 0.13 rem that does not include film badge doses lower that the detection limit and represents the mode of all film badge results.
- The number of hours spent topside is increased from the default 8 to 16 hr day^{-1}.
- A deck shielding factor of 0.15 (fraction transmitted) for time spent below deck is used (Thomas et al., 1983).
- The breathing rate associated with intakes of contaminated materials by inhalation is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the WIGWAM Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation while topside aboard ship.	USS CHANTICLEER crew members were exposed to topside radioactive contamination from contaminated water spray and mist.	Assumed 16 hr day^{-1} topside instead of 9.6 hr day^{-1}. Assumed a film badge result of 0.13 rem for all crew members.
Residual radiation while below deck aboard ship.	USS CHANTICLEER crew members were exposed to external gamma radiation from top side, hull, and salt water system contamination while below deck for all times from May 15, 1955 until one year after the start of the operation to account for crew remaining on the USS CHANTICLEE after the end of the operation (May 17, 1956).	Deck shielding factor (fraction transmitted) was increased from 0.1 to 0.15. (Thomas, 1983)
INTERNAL		
Inhalation of resuspended contamination while topside.	USS CHANTICLEER crew members were subjected to inhalation of contamination resuspended from the weather decks. The deck contamination was assumed to have been deposited by contaminated mist and spray while the USS CHANTICLEER operated in contaminated waters.	Assumed a breathing rate of 2 m^3 hr^{-1}, instead of the default 1.2 m^3 hr^{-1}. Assumed 16 hr day^{-1} topside instead of 9.6 hr day^{-1}.
Inhalation of resuspended contamination while performing decontamination operation.	USS CHANTICLEER crew members were subjected to inhalation of contamination resuspended from the weather decks for 4 hours on May 15, 1956	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$	Start Date for USS CHANTICLEER exposures [time]	May 14, 1955
$Date_{WM}$	Date and time of shot during Operation WIGWAM	May 14, 1955 [1300]
$Date_{Departed}$	End Date for USS CHANTICLEER exposures from fixed residual contamination on the USS CHANTICLEER	May 17, 1956
$Date_{FBtturnin}$	The date that the film badge was turned in.	May 17, 1955
EXTERNAL DOSE		
$Dose_{FILM}$	The film badge dose used to reconstruct the external dose	0.13 rem (Weary et al., 1981)
$Time_{Decon}$	The time assumed to decontaminated the USS CHANTICLEER	4 hrs (SAIC, 1981)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
F_{ts}	Fraction of time spent topside on USS CHANTICLEER (time exposed to external radiation)	0.67 (= 16/24)
Fraction Below Deck	Fraction of time spent below deck on USS CHANTICLEER (time exposed to shielded external radiation)	0.33 ($= 1 - F_{ts}$)
Shielding Factor	Shielding factor (fraction transmitted) while below deck	0.15 (Thomas, 1983)
λ	Decay Exponent	1.2 (DTRA, 2010, SM ED-02)
F_{decon}	Decontamination Factor to lower exposure rates after decontamination	0.4
Film badge dose	Dose received from external exposure while topside due to radioactive contamination and below deck contamination	0.13 rem (SAIC, 1981)

Table 3. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 $m^3\ hr^{-1}$
K_{Ship}	Resuspension factor for resuspension of contamination from ship surfaces	K = 10^{-5} (DTRA, 2010, SM ID01)
K_{Decon}	Resuspension factor for resuspension of contamination from ship surfaces during decontamination	K = 10^{-4} (DTRA, 2010, SM ID01)
$T_{resuspend}$	Duration of contamination resuspension from ship surfaces	The period from the start of entry into the contaminated area (H+16) to 100 hours following the start of entry into the contaminated area (H+116).
GSMF	Gamma Source Modification Factor	4.4 (Weitz, 2010)
DCF_{inhFBE} DCF_{Ing}	Inhalation dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 μm) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the WIGWAM ship-based personnel are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for WIGWAM Ship-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	0.3		0.6	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha†	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.001	<0.001	0.007
Bone Surface	0.02	0.005	0.2	0.05
Brain	<0.001	<0.001	<0.001	0.004
Breast	<0.001	0.001	<0.001	0.006
Stomach Wall	<0.001	0.004	<0.001	0.04
Small Intestine Wall	<0.001	0.007	<0.001	0.07
Upper Large Intestine Wall	<0.001	0.03	<0.001	0.3
Lower Large Intestine Wall	<0.001	0.05	<0.001	0.5
Kidney	<0.001	0.001	<0.001	0.007
Liver	0.003	0.001	0.03	0.009
Extra-Thoracic Region	<0.001	0.08	0.002	0.8
Lung	<0.001	0.07	0.003	0.7
Muscle	<0.001	0.001	<0.001	0.006
Pancreas	<0.001	0.001	<0.001	0.007
Red Marrow	0.001	0.002	0.006	0.02
Spleen	<0.001	0.001	<0.001	0.006
Testes	<0.001	0.001	0.002	0.004
Thymus	<0.001	0.001	<0.001	0.007
Thyroid	<0.001	0.1	<0.001	1
Urinary Bladder Wall	<0.001	0.003	<0.001	0.03

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Stuart, J., Goetz, J., and Klemm, J., 1983, *Analysis of Radiation Exposure for Naval Personnel at Operation IVY.* DNA TR-82-98, Defense Nuclear Agency, Washington, DC, March 15

SAIC, 1981, "History of USS CHANTICLEER (ASR-7) During Operation WIGWAM", May.

Weary, S.E., Ozerroff, W.J., Sperling, J.L., Collins, B., Lowery, C.W., and Obermiller, S.K., 1981. *Operation WIGWAM.* 6000F, Defense Nuclear Agency, Washington, DC. September 1.

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1).* NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Operation REDWING Ship-Based Personnel

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<u>Important Note</u>

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Expedited Processing Group: Operation REDWING Ship-Based Personnel

1. Description of the Expedited Processing Group

The Operation REDWING Ship-Based Personnel Expedited Processing Group (EPG) consists of approximately 4,000 military personnel who were assigned to U.S. Navy ships during Operation REDWING (1956) (Bruce-Henderson et al., 1982; DTRA, 2008, Appendix B-7). Although general activities of the crew members of the various ships were different, their activities that may have resulted in exposure to residual radiation were similar. Furthermore, the sources of radiation exposure and activities resulting in exposure of these participants involving relevant REDWING shots were similar. Therefore it is reasonable to include most participants assigned as ships' crew members during Operation REDWING in a single EPG.

Operation REDWING is described in Bruce-Henderson et al. (1982). A list of the participating ships is included in Table 1. A list of transient ships that were in the area during the operation is included in Table 2 (Bruce-Henderson et al., 1982).

There are no specific exclusions for this EPG.

Table 1. Naval Ships that Participated in Operation REDWING

Ship	Arrival Date (1956)	Departure Date (1956)	Duty (Unit and Task Unit)	Size
USS ABNAKI (ATF-96)	Mar 19	Jul 27, 1956	Utility (7.3.2)	73
USNS FRED C. AINSWORTH (T-AP-181)	Apr 25	Jul 23	Accommodation (7.3.9)	21 146 civilians
USS BADOENG STRAIT (CVE-116)	Mar 16	Jul 26	Carrier (7.3.1)	724 151 (Marine Corps Helicopter Unit)
USNS BERNALILLO COUNTY (LSD-306)	Feb 27	Jul 25	Utility (7.3.2)	49
USS CATAMOUNT (LSD-17)	Feb 2	Jul 23	Boat Pool (7.3.7)	260
USS CHICKASAW (ATF-83)	Apr 2	Jul 26	Utility (7.3.2)	72
USS CROOK COUNTY (LST-611)	Apr 8	Unknown	Rad Support (7.3.6)	80
USS CURTISS (AV-4)	Apr 10	Jul 26	Special Devices (7.3.8)	560
USS ESTES (AGC-12)	Mar 31	Jul 25	Flagship (7.3.0)	550
USS GEORGE EASTMAN (YAG-39)	Mar 28	Jul 28	Rad Support (7.3.6)	51
USS GRANVILLE S. HALL (YAG-40)	Mar 28	Jul 28	Rad Support (7.3.6)	51

Table 1. Naval Ships that Participated in Operation REDWING (cont.)

Ship	Arrival Date (1956)	Departure Date (1956)	Duty (Unit and Task Unit)	Size
USS KNUDSON (APD-101)	Apr 10	Jul 23	Surface Patrol and Transport (7.3.3)	156
USS J.E. KYES (DD-787)	Apr 10	Jul 25	Surface Patrol and Transport (7.3.3)	346
USS LIPAN (ATF-85)	Mar 30	Jul 21	Utility (7.3.2)	69
USS MCGINTY (DE-365)	Apr 10	Jul 28	Surface Patrol and Transport (7.3.3)	157
USS MOUNT MCKINLEY (ACG-7)	May 15	May 22	Press and Observer Ship	Unknown*
USS SHELTON (DD-790)	Apr 10	Jul 25	Surface Patrol and Transport (7.3.3)	228
USS SILVERSTEIN (DE-534)	Apr 10	Jul 25	Surface Patrol and Transport (7.3.3)	155
USS SIOUX (ATF-75)	Mar 22	Jul 24	Utility (7.3.2)	68
USS WALTON (DE-361)	Jun 5	Jun 23	Rad Support (7.3.6)	Unknown
			Total	3,918 plus unknowns

* The USS MOUNT MCKINLEY was not apart of the naval task force but was used by observers and the media.

Table 2. Transient Ships that were Present in the PPG during Operation REDWING

Ship	Arrival Date (1956)	Departure Date (1956)	Duty (unit and Task Unit)	Size
USS AGAWAM (AOG-6)	May 21,	Jul 16	Oiler	131
USS CALIENTE (AO-53)	July 3	Aug 1	Oiler	220
USS CIMARRON (AO-22)	Early Aug	Late Aug	Oiler	Unknown
USS ELKHORN (AOG-7)	Early May	Late may	Oiler	Unknown
USS KARIN (AF-33)			Oiler	Unknown
USS KISHWAUKEE (AOG-9)	June 3	July 15	Oiler	Unknown
USS MERAPI (AF-38				
USS MISPILLION, (AO-105)	Early May	Late May	Oiler	Unknown
USS NAMAKAGON (AOG-53)	Jun 8	July 21	Oiler	Unknown
USNS PVT JOE E. MANN (T-AK-253)	May	Jul	Cargo	16
USS NATCHAUG (AOG-54)	June 16	June 19	Oiler	Unknown
USS NAVASOTA (A-106)	May	June	Oiler	Unknown
USS NEMASKET (APG-10)	Jul	Jul	Oiler	Unknown
USS SUSSEX (AF-213)	Jun 11	Jul 27	Cargo	38
USNS SGT ARCHER T. GAMMON (T-AK-243)	Jun 7	Jun 11	Transport	16

2. Basis for Operation REDWING, Ship-Based Personnel

To estimate EPG doses for all Operation REDWING Ship-Based Personnel, an exposure scenario was developed based on activities of the cohort group that received the highest dose from exposure to external radiation and corresponding internal doses. This cohort is referred to as the "highest-dose cohort". Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of the USS SILVERSTEIN form the basis for the highest-dose cohort scenario (DTRA, 2008, Appendix B-7) for two primary reasons:

- This group received the largest external gamma dose from residual radiation of all Operation REDWING ship-based personnel.
- The activities of this group are well-documented and are representative of other Operation REDWING ship-based personnel.

As explained below, several dose components and assumptions were added to the documented USS SILVERSTEIN scenario (Bruce-Henderson et al., 1982). The basic scenario of participation and radiation exposure of the USS SILVERSTEIN is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: USS SILVERSTEIN

To estimate EPG doses for all military personnel assigned to U.S. Navy ships during Operation REDWING, a basic high-sided exposure scenario was developed based on activities of the crew members of the U.S. Navy ship, the USS SILVERSTEIN. The crew members of the USS SILVERSTEIN received the highest average external dose of any crew members (DTRA, 2008, Appendix B-7). The fallout episodes experienced by the USS SILVERSTEIN are listed in Table 3 (DTRA, 2008, Appendix B-7).

USS SILVERSTEIN was a destroyer escort assigned to the Surface Patrol and Transport Unit (Task Unit 7.3.3) whose primary mission was to support Project 2.62a. This support involved entry into areas of predicted fallout, as soon as radiological conditions permitted, for the collection of surface water samples and measurement of surface and sub-surface gamma radiation levels (Bruce-Henderson et al., 1982).

The USS SILVERSTEIN cohort exposure scenario is described directly below, followed by a description of the additional assumptions.

The radiation exposure rates aboard USS SILVERSTEIN during and shortly after the five fallout events are listed in Table 3 and displayed in Figure 1 to Figure 5. Based on these exposure rates, decayed to the end of the USS SILVERSTEIN participation, USS SILVERSTEIN crew members accrued external doses from deposited fallout while topside and while below deck. They are assumed to have spent all day every day on board ship during the period April 4–July 27, 1956 except for shore liberty. They also received internal doses from resuspended fallout for the first 100 hours after each fallout episode during the same period (DTRA, 2008, Appendix B-7).

Table 3. Peak Radiation Exposure Rates on USS SILVERSTEIN during Operation REDWING

Shot	Shot Date (1956) (Time)	Peak Exposure Rate ($R\ hr^{-1}$)	Time of Peak Exposure (H+)
ZUNI	May 28 (0556)	0.020	32
FLATHEAD	Jun 26 (0626)	0.00143	35.5
MOHAWK	Jul 3 (0606)	0.003	2.4
MOHAWK	Jul 3 (0606)	0.00208	13.9
NAVAJO	Jul 11 (0556)	0.00149	22
TEWA	Jul 21 (0546)	0.00368	18.25

The USS SILVERSTEIN crew also accrued external doses from four other sources: accumulated radioactive materials on its underwater hull, radioactive contamination in salt water piping and evaporators, radiation "shine" from contaminated lagoon water, and radioactive fallout in beach and shore areas during shore liberty. Although partially attenuated by the hull and piping structures, the gamma radiation emitted by these contaminants was a source of exposure to crewmembers in below-deck spaces. Crewmen who were topside when the ship operated in contaminated water were exposed to gamma radiation emitted directly from the contaminants in the water. Crew members were exposed to radioactive fallout while on Bikini and Enewetak Atoll during shore liberty. (DTRA, 2008, Appendix B-7)

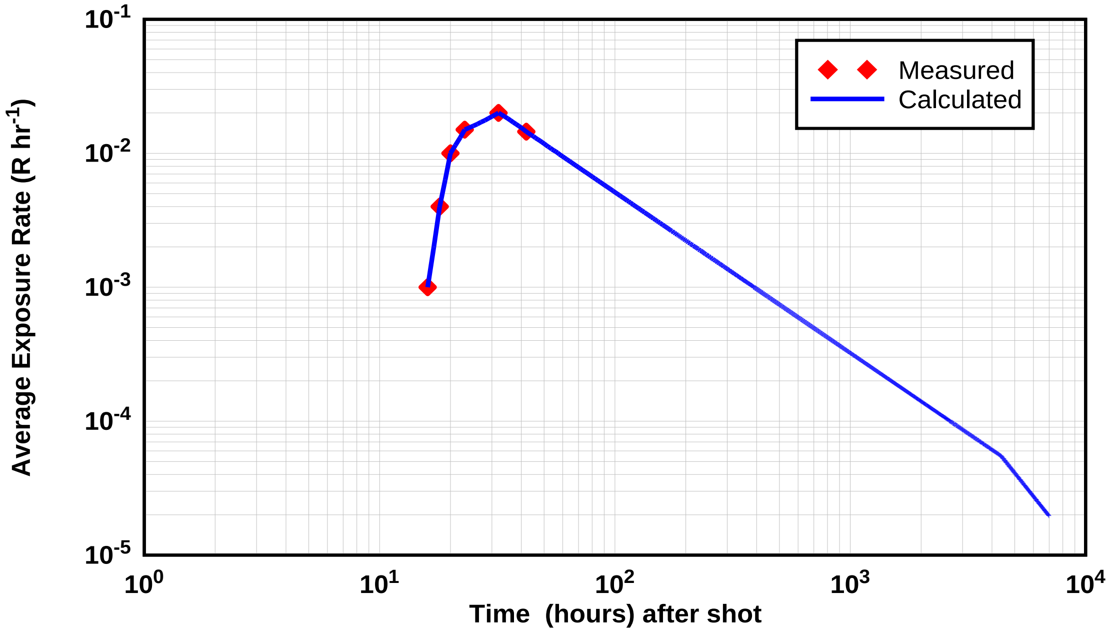

Figure 1. Average Topside Residual Radiation Exposure Rate on USS SILVERSTEIN from Shot ZUNI

Figure 2. Average Topside Residual Radiation Exposure Rate on USS SILVERSTEIN from Shot FLATHEAD

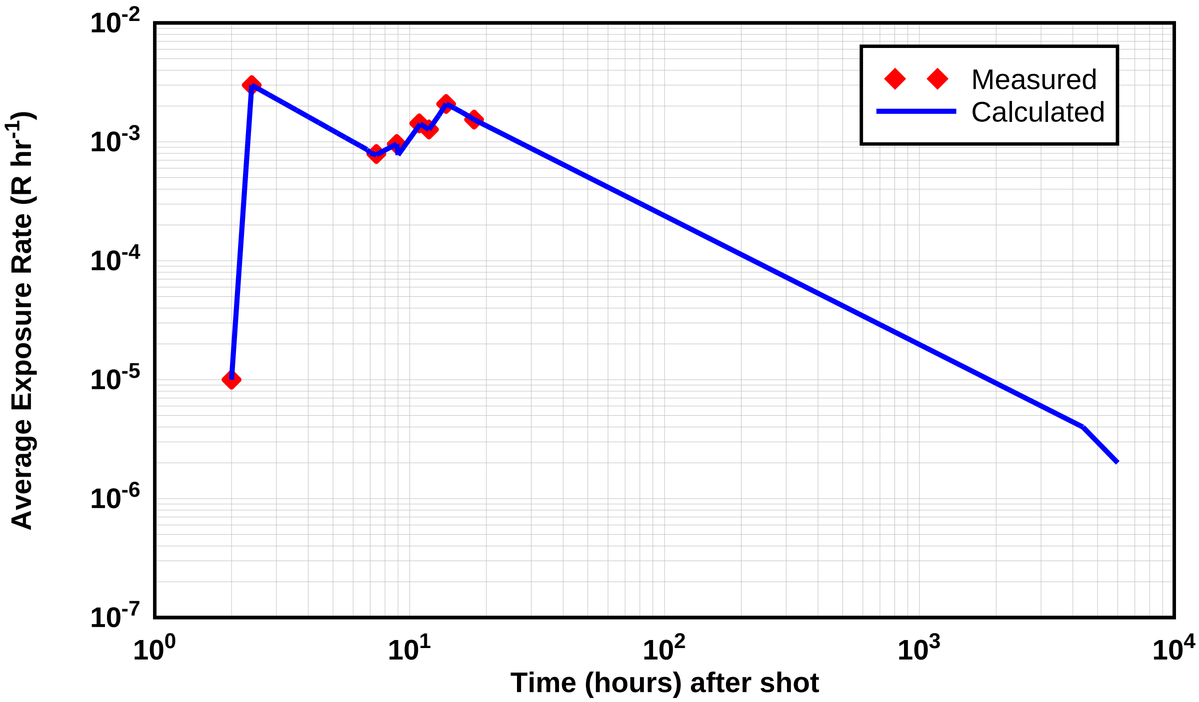

Figure 3. Average Topside Residual Radiation Exposure Rate on USS SILVERSTEIN from Shot MOHAWK

Figure 4. Average Topside Residual Radiation Exposure Rate on USS SILVERSTEIN from Shot NAVAJO

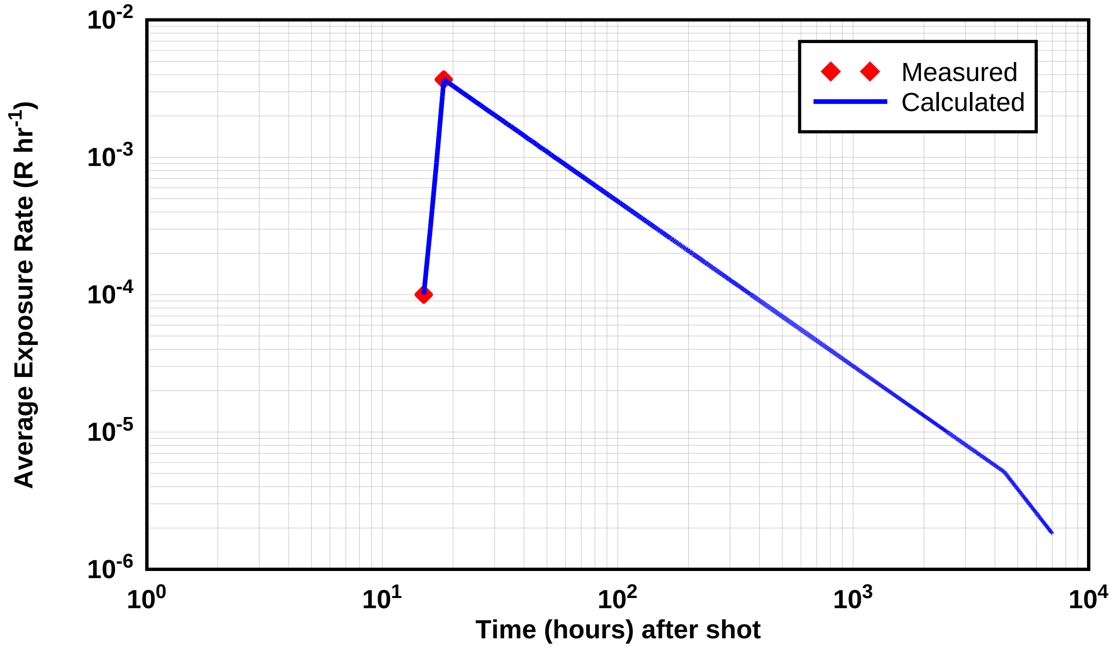

Figure 5. Average Topside Residual Radiation Exposure Rate on USS SILVERSTEIN from Shot TEWA

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided USS SILVERSTEIN cohort analysis:

- The period of assignment to USS SILVERSTEIN is assumed to include the entire potential period of exposure to fallout while USS SILVERSTEIN was in the PPG. The assignment period used is from the onset of ZUNI fallout until USS SILVERSTEIN departed from the PPG (May 5–July 25) (DTRA, 2008, Appendix B-7).
- The number of hours spent topside is increased from 8 to 16 hr day^{-1}.
- A shielding factor of 0.15 (fraction transmitted) for time spent below deck is used instead of 0.14 (Thomas et al., 1983).
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption that personnel activities consisted of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 4. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 5.

Table 4. Exposure Pathways for the REDWING Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation while topside and while below deck aboard ship during and after Operation REDWING.	USS SILVERSTEIN crew members were exposed to residual radiation due to ZUNI, FLATHEAD, MOHAWK, NAVAJO and TEWA fallout while topside..	The number of hours spent topside is increased from 8 to 16 hr day^{-1}. Shielding factor (fraction transmitted) is the highest possible value at 0.15 instead of 0.14.
Residual radiation from hull contamination while below deck during and after Operation REDWING.	SS SILVERSTEIN crew members were exposed to residual radiation from accumulated radioactive materials on the underwater hull for approximately 150 days (SAIC, 1992).	
Residual radiation from contaminated salt water system while below deck during and after Operation REDWING.	USS SILVERSTEIN crew members were exposed to residual radiation from accumulated radioactive materials in salt water piping and evaporators for approximately 150 days (SAIC, 1992).	
Residual radiation from lagoon contamination while topside during Operation REDWING.	USS SILVERSTEIN crew members were exposed to external gamma radiation from contaminated lagoon water during and just after episodes of fallout (SAIC, 1992).	The number of hours spent topside is increased from 8 to 16 hr day^{-1}
Residual radiation in the recreation areas while on shore liberty during Operation REDWING.	USS SILVERSTEIN crew members were exposed to residual radiation while on shore for shore liberty from Shots ZUNI MOHAWK, APACHE, and TEWA.	Assumed shore liberty for 4 hours every 4th day with entire shore liberty time spent outside.
INTERNAL		
Inhalation of resuspended fallout while topside during and after Operation REDWING.	USS SILVERSTEIN crew members were subjected to inhalation of airborne fallout resuspended from the weather decks. The resuspended fallout was from shots ZUNI, FLATHEAD, MOHAWK, NAVAJO and TEWA. (DTRA, 2008, Appendix B-7).	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed shore liberty for 4 hours every 4th day with entire shore liberty time spent outside.
Inhalation of resuspended fallout while on shore liberty during Operation REDWING	USS SILVERSTEIN crew members were subjected to inhalation of airborne fallout resuspended while on shore liberty. The resuspended fallout was from shots ZUNI, MOHAWK, APACHE and TEWA.	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of fallout during Operation REDWING	USS SILVERSTEIN crew members were subjected to incidental ingestion of fallout while on shore liberty. The fallout was from shots ZUNI, MOHAWK, APACHE and TEWA. (DTRA, 2008, Appendix B-7).	Assumed shore liberty for 4 hours every 4th day with entire shore liberty time spent outside.

Table 5. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
Date Arrived in PPG	Start Date for USS SILVERSTEIN exposures[time]	10 April 1956
DateDeparted PPG	End Date for USS SILVERSTEIN exposures from Shore Liberty	27 July1956
Date Departed the USS SILVERSTEIN	End Date for USS SILVERSTEIN exposures from residual contamination on the USS SILVERSTEIN	10 April 1957
EXTERNAL DOSE		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
SF	Shielding factor (fraction transmitted) while below deck	0.15 (Thomas et al, 1983)
$Ipeak_{ZN}$ $Tpeak_{ZN}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZUNI	0.02 R hr^{-1} at H+32 (DTRA, 2008, Appendix B-7)
$Ipeak_{FL}$ $Tpeak_{FL}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot FLATHEAD	0.00143 R hr^{-1} at H+ 35.5 (DTRA, 2008, Appendix B-7)
$Ipeak_{MO1}$ $Tpeak_{MO1}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MOHAWK, 1st Episode	0.003 R hr^{-1} at H+ 2.4 (DTRA, 2008, Appendix B-7)
$Ipeak_{MO2}$ $Tpeak_{MO2}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MOHAWK 2nd Episode	0.00208 R hr^{-1} at H+13.9 (DTRA, 2008, Appendix B-7)
$Ipeak_{NV}$ $Tpeak_{NV}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot NAVAJO	0.00149 R hr^{-1} at H+22 (DTRA, 2008, Appendix B-7)
$Ipeak_{TW}$ $Tpeak_{TW}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot TEWA	0.00368 R hr^{-1} at H+18.25 (DTRA, 2008, Appendix B-7)
$Ipeak_{ZNland}$ $Tpeak_{ZNland}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZUNI on land	0.00025 R hr^{-1} at H+11 (DTRA, 2008, Appendix B-7)
$Ipeak_{MOland}$ $Tpeak_{MOland}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MOHAWK on land	0.0195 R hr^{-1} at H+2.9 (DTRA, 2008, Appendix B-7)
$Ipeak_{APland}$ $Tpeak_{APland}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot APACHE on land	0.00084R hr^{-1} at H+20.9 (DTRA, 2008, Appendix B-7)
$Ipeak_{TWland}$ $Tpeak_{TWland}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot TEWA on land	0.01155R hr^{-1} at H+25 (DTRA, 2008, Appendix B-7)
λ_{postop}	Decay exponent for times less than H+ 4380	1.2 (DTRA, 2008, Appendix B-7)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-7)
Frequency of Shore Liberty	The frequency and time of shore liberty on Enewetak Island	4 hours every four days

Table 5. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K_{ShipDet}$	Resuspension factor for resuspension of fallout from ship surfaces	K = 10^{-5} (DTRA, 2010, SM ID01)
F_{ts}	Fraction of time spent topside on USS SILVERSTEIN (time exposed to resuspended fallout)	0.67 (= 16/24)
$GSMF_{ZN}$	Gamma Source Modification Factor for Shot ZUNI (average of YAG-39 and Eneu Island)	1.5 (DTRA, 2008, Appendix B-7)
$GSMF_{FL}$	Gamma Source Modification Factor for Shot FLATHEAD (USNS FRED AINSWORTH)	3 (Weitz, 2010)
$GSMF_{MO1}$	Gamma Source Modification Factor for Shot MOHAWK 1st Episode (LST-306)	3.2 (Weitz, 2010)
$GSMF_{MO2}$	Gamma Source Modification Factor for Shot MOHAWK 2nd Episode (Parry Island)	1 (DTRA, 2008, Appendix B-7)
$GSMF_{NV}$	Gamma Source Modification Factor for Shot NAVAJO (USNS FRED AINSWORTH)	3 (Weitz, 2010)
$GSMF_{TW}$	Gamma Source Modification Factor for Shot ZUNI (Eneu Island)	1 (DTRA, 2008, Appendix B-7)
$Frac_{SL}$	Fraction of time spent on shore liberty	4 hr every 4th day 0.0417 = 4/(24 × 4)
K_{Ship}	Resuspension factor for resuspension of fallout from ship surfaces	K = 10^{-5} (SM ID01 of DTRA, 2010)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate during shore liberty periods	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density during shore liberty periods	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{InhAct} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the REDWING ship-based personnel are summarized in Table 6. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 6 are not less than the upper bound doses potentially accrued by any member of the EPG.

Table 6. External and Internal Doses and Upper Bounds for REDWING Ship-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	3		7	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.001	<0.001	0.01
Bone Surface	0.009	0.01	0.09	0.1
Brain	<0.001	0.001	<0.001	0.005
Breast	<0.001	0.001	<0.001	0.008
Stomach Wall	<0.001	0.005	<0.001	0.05
Small Intestine Wall	<0.001	0.01	<0.001	0.09
Upper Large Intestine Wall	<0.001	0.04	<0.001	0.4
Lower Large Intestine Wall	<0.001	0.08	<0.001	0.8
Kidney	<0.001	0.002	<0.001	0.02
Liver	0.002	0.002	0.02	0.02
Extra-Thoracic Region	<0.001	0.2	<0.001	2
Lung	<0.001	0.2	0.002	2
Muscle	<0.001	0.001	<0.001	0.009
Pancreas	<0.001	0.001	<0.001	0.01
Red Marrow	<0.001	0.003	0.005	0.03
Spleen	<0.001	0.001	<0.001	0.008
Testes	<0.001	0.001	0.002	0.005
Thymus	<0.001	0.002	<0.001	0.02
Thyroid	<0.001	0.2	<0.001	2
Urinary Bladder Wall	<0.001	0.003	<0.001	0.03

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 6 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 7. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 7. Cancers not Recommended for Expedited Processing for Operation REDWING Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	8

6. References

Berkhouse, L.H., Bruce-Henderson, S., Davis, S., Dean, P., DeSantis, H., Doyle, M.K.,Gladeck, F.R., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.H., Patterson, D.S., Rogers, W.E., Rowland, R.H., Shelton, C.F., and Sturman, P., 1956. *Operation REDWING*: *1956.* DNA 6037F, Defense Nuclear Agency, Washington, DC. August 1.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

SAIC, 1992, *USS SILVERSTEIN, Operation REDWING, Ship Contamination and Shine Calculations*, SAIC, McLean, VA. November 10.

Thomas, C., Goetz, J., Stuart, J., and Klemm, J., 1983. *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*. DNA-TR-82-98. Defense Nuclear Agency, Washington, DC. March 15.

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1).* NTPR-TM-09-04 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure
for Expedited Processing

Operation REDWING
Land-Based Personnel

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation REDWING Land-Based Personnel

1. Description of the Expedited Processing Group

The Operation REDWING Land-Based Personnel Expedited Processing Group (EPG) generally consists of approximately 5,000 military personnel who were assigned to Enewetak Atoll consisting of Enewetak, Parry, and Japtan; to Eneu Island, to Kwajalein Atoll, or to the weather islands of Tarawa, Rongerik, Kusaie, and Kapingamarangi during any period of the operation (Berkhouse et al., 1982; DTRA, 2008, Appendix B-7). The land-based personnel had a wide range of assignments but their activities would have resulted in exposures to residual radiations that were similar. Furthermore, the sources of radiation exposure and activities resulting in exposure of these personnel from relevant REDWING shots were similar. Therefore it is reasonable to include all land-based personnel in a single EPG. There are no specific exclusions for this EPG.

REDWING is described in Berkhouse et al. (1982). The units included in the EPG are listed in Table 1.

Table 1. Island Resident Units during Operation REDWING

Unit	Size
Headquarters, Joint Task Force 7	327
Task Group 7.1, Scientific	519
505th Military Police Battalion	255
902nd Counter-Intelligence Corps Detachment	8
7126th Army Unit	1,035
8452nd Anti-Aircraft Artillery Unit	1
8600th Army Unit, 2nd Army Security Agency	42
Patrol Squadron One	354
Transport Squadron Three	181
Transport Squadron Eight	10
Enewetak Boat Pool	39
Bikini Boat Pool	203
Headquarters, Task Group 7.4	123
Test Base Unit	93
4931st Operations Squadron	221
4932nd Maintenance Squadron	375
Helicopter Element	50
Test Aircraft Unit	550
Test Services Unit	1,044
Miscellaneous	23
Total	5,453

2. Basis for REDWING Land-Based Personnel

To estimate EPG doses for all REDWING land-based personnel an exposure scenario was developed based on activities of the land-based personnel group that received the highest dose from exposure to external residual radiation and corresponding internal doses. This cohort is referred to as the "highest-dose cohort." Exposures to initial neutron and gamma radiation are not taken into consideration when selecting a "highest-dose cohort" because these activities are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of the members of the 7126th Army Unit form an adequate basis of the generic highest-dose cohort scenario for this EPG for four primary reasons:

- This group was the largest cohort that was in residence on Enewetak Atoll.
- The group was in residence at Enewetak Atoll for the duration of Operation REDWING.
- Most of the subunits of the 7126th Army Unit were not involved in Radsafe activities such as monitoring or decontamination that would increase the dose received well above other members of the cohort.
- The Enewetak island residents were not evacuated during any shot nor took any special precautions.

As explained below, several dose components and assumptions were added to the documented 7126th Army Unit scenario (Berkhouse et al., 1982) to produce EPG doses. The basic scenario of participation and radiation exposure of the 7126th Army Unit is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: 7126th Army Unit Scenario

To estimate EPG doses for all military personnel assigned to the 7126th Army Unit during REDWING, a generic high-sided exposure scenario was develop based upon activates of the 7126th Army Unit. Approximately 1050 members of the Army were assigned to the 7126th Army Unit during REDWING. Most service members assigned to the 7126th Army Unit arrived before April 18, 1956 and stayed until the end of the REDWING on August 6, 1956. Members of the 7126th Army Unit lived in tents or barracks on Enewetak Atoll and had their meals in indoor dining facilities. Table 2 lists the fallout events on Enewetak Atoll during Operation REDWING. The calculated exposure rates due to each descending fallout event are included in Figure 1 to Figure 4 (DTRA, 2008, Appendix B-7; Berkhouse et al., 1982).

Table 2. Fallout on Enewetak during Operation REDWING

REDWING Shot	SHOT Date/Time (1956)	Peak Exposure Rate Measured on Enewetak Atoll (R hr^{-1})	Time of Peak Exposure Rate (H+hr)
ZUNI	May 28 at 0556	0.00025	11
MOHAWK	Jul 3 at 0606	0.012	3
APACHE	Jul 9 at 0606	0.00084	20.9
TEWA	Jul 21 at 0546	0.12	25

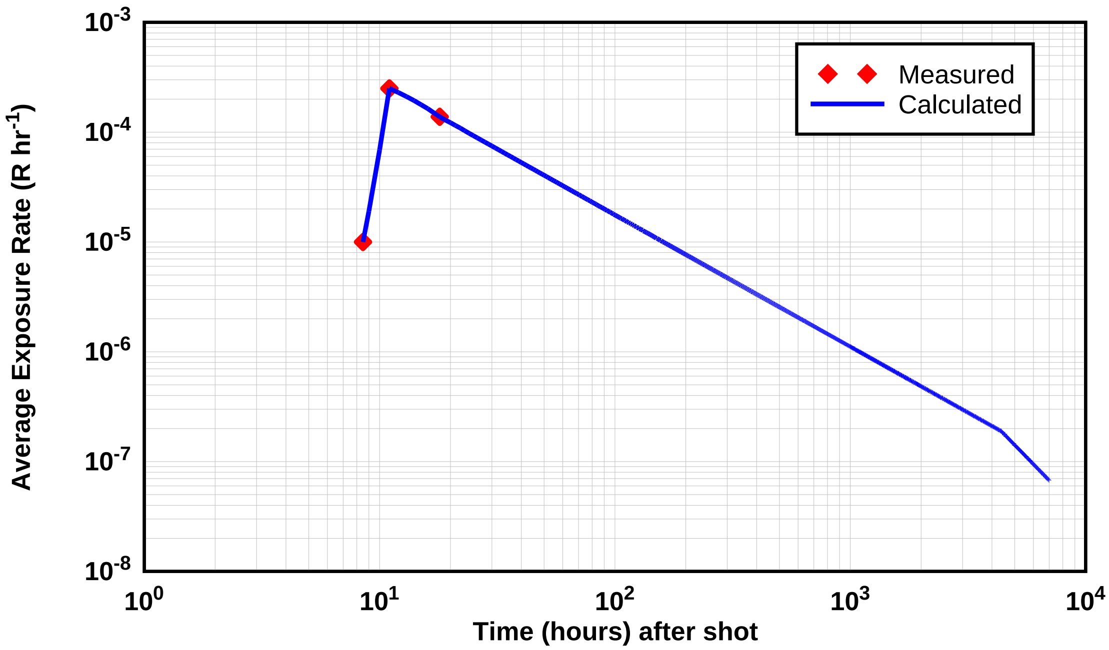

Figure 1. Residual Radiation Exposure Rate on Enewetak from Shot ZUNI

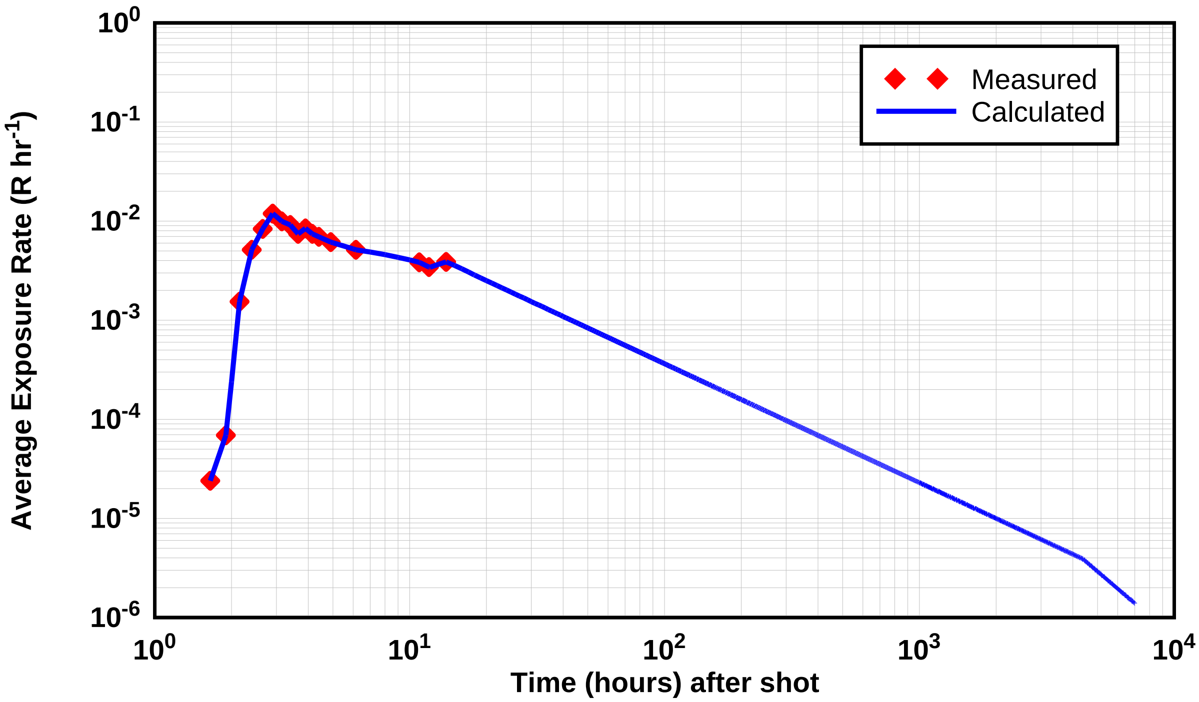

Figure 2. Residual Radiation Exposure Rate on Enewetak from Shot MOHAWK

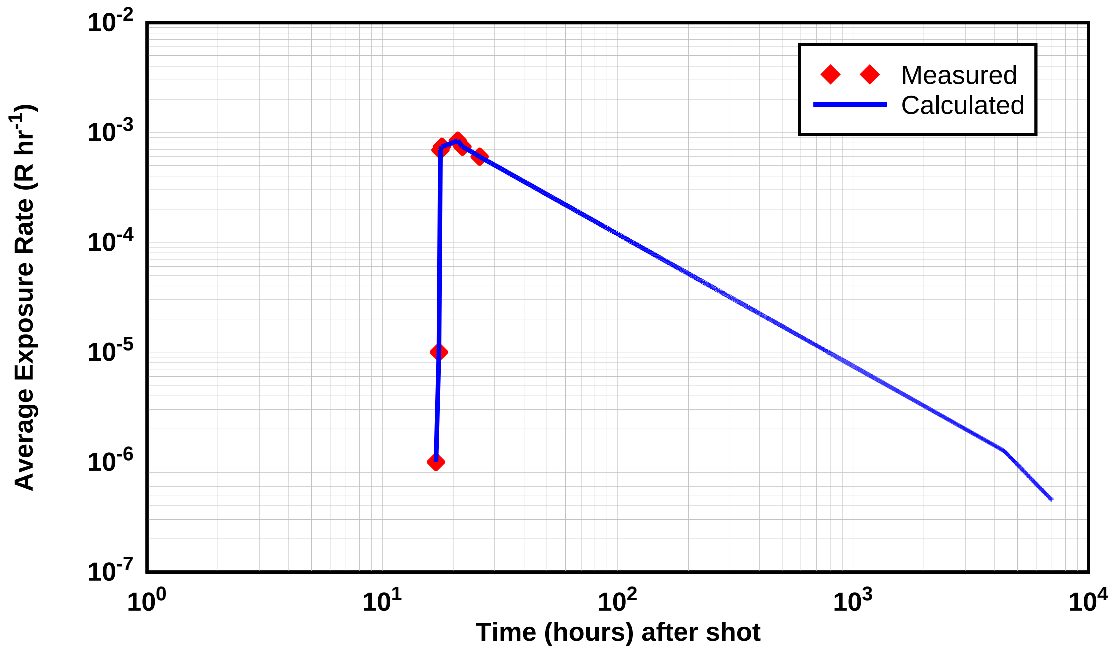

Figure 3. Residual Radiation Exposure Rate on Enewetak from Shot APACHE

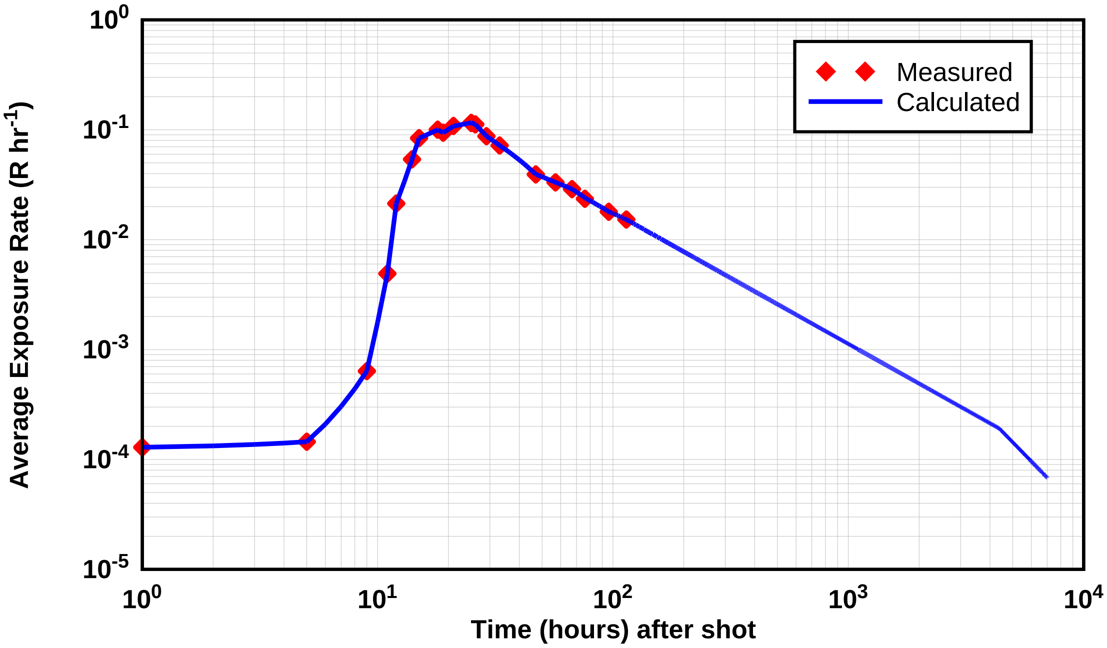

Figure 4. Residual Radiation Exposure Rate on Enewetak from Shot TEWA

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided 7126th Army Unit cohort analysis:

- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1} assuming that 8 hours were spent indoors for sleeping, cleaning and eating (DTRA, 2010, ED02).
- Although personnel spend their time indoors in either a tent or a metal building, it is assumed that they spent 100 percent of this time in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2 (DTRA, 2010, ED02).
- The Enewetak Island residents are assumed to be outdoors during descending fallout and the fallout was considered light enough so that daily duty routines were not altered (Thomas et al., 1984).
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of 50% light activity and 50% moderate activity (Weitz et al, 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure pathways for the REDWING Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from Operation CASTLE shots	7126th Army Unit members were exposed to residual radiation due to fallout from Operation CASTLE shots for three months prior to the start of Operation REDWING (January 18, 1956).	Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside. Used the lowest protection factor while indoors (1.5 for tents).
Residual radiation from four shots during Operation REDWING	7126th Army Unit members were exposed to residual radiation due to fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA during the operational period and for one year following the end of Operation REDWING.	Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside. Used the lowest protection factor while indoors (1.5 for tents). .
INTERNAL		
Inhalation of descending fallout from four fallout episodes	7126th Army Unit members were subjected inhalation of descending fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA.	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside.
Inhalation of resuspended fallout from Operation CASTLE	7126th Army Unit members were subjected to inhalation of resuspended fallout from Operation CASTLE shots for three months prior to the start of Operation REDWING (January 18, 1956).	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside.
Inhalation of resuspended fallout from four fallout episodes	7126th Army Unit members were subjected to inhalation of resuspended fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA.	Assumed a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Assumed 16 hr day^{-1} outside instead of 14.4 hr day^{-1} outside.
Incidental ingestion of contaminated soil/dust from Operation CASTLE shots	7126th Army Unit members incurred doses from incidental ingestion of soil and dust contaminated with fallout from Operation CASTLE shots for three months prior to the start of Operation REDWING (January 18, 1956).	
Incidental ingestion of contaminated soil/dust from four fallout episodes	7126th Army Unit members incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA.	

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$	Enewetak arrival date	January 18, 1956
$Date_{StartOp}$	REDWING start date[time]	18 Apr 1956 [0800]
$Date_{EndOp}$	REDWING end date[time]	August 6, 1956 [2400]
$Date_{Departed}$	Enewetak departure date[time]	August 6 , 1957 [2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Atoll	0.67 (= 16/24)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
PF_t	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
$IpeakDet_{ZN}$ $TpeakDet_{ZN}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZUNI	0.00025 R hr^{-1} at H+11 (DTRA, 2008, Appendix B-7)
$IpeakDet_{MH}$ $TpeakDet_{MH}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MOHAWK	0.012 R hr^{-1} at H+3 (DTRA, 2008, Appendix B-7)
$IpeakDet_{AP}$ $TpeakDet_{AP}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot APACHE	0.00084 R hr^{-1} at H+20.9 (DTRA, 2008, Appendix B-7)
$IpeakDet_{TW}$ $TpeakDet_{TW}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot TEWA	0.12 R hr^{-1} at H+25 (DTRA, 2008, Appendix B-7)
λ_{postop}	Decay exponent for times of H+ < 4380	1.2 (DTRA, 2008, Appendix B-7)
λ_{6mon}	Decay exponent for times of H+ > 4380	2.2 (DTRA, 2008, Appendix B-7)
$DoseDet_{Pre}$	External gamma dose due to fallout from Operation CASTLE residual radiation	0.006 rem (Mason, 2009)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InFBE} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)
$ResInh_{Pre}$ $IncIng_{Pre}$	Internal doses due to fallout from Operations CASTLE residual radiation	See Mason, 2009 for a list of organ doses

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the REDWING land-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper- external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for REDWING Land-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	6		18	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.02	0.02	0.2
Bone Surface	0.9	0.5	9	5
Brain	0.002	0.01	0.02	0.2
Breast	0.002	0.02	0.02	0.2
Stomach Wall	0.002	0.2	0.02	2
Small Intestine Wall	0.002	0.3	0.02	3
Upper Large Intestine Wall	0.002	1	0.02	9
Lower Large Intestine Wall	0.002	2	0.02	16
Kidney	0.004	0.04	0.04	0.4
Liver	0.2	0.09	2	0.9
Extra-Thoracic Region	0.009	3	0.09	25
Lung	0.02	3	0.2	30
Muscle	0.002	0.02	0.02	0.2
Pancreas	0.002	0.02	0.02	0.2
Red Marrow	0.05	0.07	0.5	0.7
Spleen	0.002	0.02	0.02	0.2
Testes	0.02	0.02	0.2	0.2
Thymus	0.002	0.03	0.02	0.3
Thyroid	0.002	3	0.02	23
Urinary Bladder Wall	0.002	0.07	0.02	0.6

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 5 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 6. Cancers not Recommended for Expedited Processing for REDWING Land-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Bile Duct	Liver	21
Esophagus	Extra-Thoracic Region	44
Gall Bladder	Liver	21
Liver	Liver	21
Thyroid	Thyroid	37
Total EPG upper-bound dose below but close to the screening dose		
Bone	Bone Surfaces	32
Stomach	Stomach Wall	20
Colon	Lower Large Intestine Wall	34
Lung	Lung	49
Acute Lymphocytic Leukemia	Red Bone Marrow	20
Parathyroid	Thyroid	41

6. References

Berkhouse, L.H., Bruce-Henderson, S., Davis, S., Dean, P., DeSantis, H., Doyle, M.K.,Gladeck, F.R., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.H., Patterson, D.S., Rogers, W.E., Rowland, R.H., Shelton, C.F., and Sturman, P., 1956. *Operation REDWING: 1956*. DNA 6037F, Defense Nuclear Agency, Washington, DC. August 1.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 3.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J. and Weitz, R. 1984. *Analysis of Radiation Exposure for Naval Personnel at Operation CASTLE.* DNA-TR-84-6, Defense Nuclear Agency, Washington, DC. February 28.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation HARDTACK I
Support Ship-Based Personnel

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Operation HARDTACK I Support Ship-Based Personnel

1. Description of the Expedited Processing Group

The HARDTACK I Support Ship-Based Personnel Expedited Processing Group (EPG) consists of the crews of support ships present at the Enewetak Proving Ground and/or Johnston Island during the operation, as listed in Table 1 (Gladeck et al., 1982).

Table 1. Support Ships that Participated in Operation HARDTACK I

USS ARIKARA	USS CARTER HALL	USNS FRED C. AINSWORTH	USS MAGOFFIN	USS ORLICK
USS BELLE GROVE	USS CHANTICLEER	USS GRASP	USS MANSFIELD	USS PERKINS
USS BENNER	USS CHOWANOC	USS HOOPER ISLAND	USS MERAPI	USS REHOBOTH
USS BOLSTER	USS COLLETT	USS JOHN R. CRAIG	USS MOCTOBI	USS RENVILLE
USS BOXER	USS CREE	USS JOYCE	USS MONTICELLO	USS SAFEGUARD
USS CABILDO	USS DeHAVEN	USS KARIN	USS MUNSEE	USS STERLET
USS CACAPON	USS ELKHORN	USS LANSING	USS NAVARRO	USS TAKELMA
USS CAPE ESPERANCE	USS FLOYD B. PARKS	USS LAWRENCE COUNTY	USS NEMASKET	USS TOMBIGBEE

The following individuals and units are excluded from expedited processing under this EPG:

- Crew members of ships that served as unmanned target vessels for the underwater shots WAHOO and UMBRELLA. Target vessels include three destroyers (KILLEN, HOWORTH, and FULLAM), a liberty ship (SS MICHAEL MORAN), and a submarine (BONITA).
- Crew members of seven ships (USS COGSWELL, USS COMSTOCK, USS EPPERSON, USS HITCHITI, USS SILVERSTEIN, USS TILLAMOOK, and USS TORTUGA) that only participated in shots at Johnston Island. These personnel form a separate EPG.

There are approximately 6,000 personnel in the HARDTACK I Support Ship-Based Personnel EPG.

2. Basis of Dose Analysis for HARDTACK I Support Ship-Based Personnel

To estimate EPG doses for Operation HARDTACK I ship-based personnel, an exposure scenario was developed based on activities of the cohort group that received the highest dose from exposure to external residual radiation and corresponding internal doses. This cohort is referred to as the “highest-dose cohort.” Exposures to initial neutron and gamma radiation are not taken into consideration when selecting a “highest-dose cohort” because these sources are not correlated to the scenario of exposure beyond the first minute after a short and are not associated with accrual of internal doses.

For this EPG, the extensive issuance of film badges for this operation facilitated the identification of this highest-dose cohort as the crew of the fleet tug USS ARIKARA. The crew members of the USS ARIKARA form an adequate basis of the generic highest-dose cohort scenario for this EPG for the following primary reasons (DTRA, 2008, Appendix B-8):

- The crew of the USS ARIKARA had the highest external doses of any ship during HARDTACK I.
- The exposures received by the crew of the USS ARIKARA are representative of exposures received by other ships during HARDTACK I.

As explained below, several dose components and assumptions were added to the documented USS ARIKARA scenario to produce EPG doses. The basic scenario of participation and radiation exposure of the crew of the USS ARIKARA is described in Section 3 followed by a description of the additional dose components and assumptions in Section 4.

3. Highest-Dose Cohort Scenario: Crew of USS ARIKARA

To estimate EPG doses for all military personnel assigned to low-dose U.S. Navy ships during Operation CASTLE, a generic high-sided exposure scenario was developed based on activities of the crew members of the USS ARIKARA. The USS ARIKARA was present at Enewetak Proving Ground for 29 of the 35 HARDTACK I shots, was assigned to decontaminate, position, and salvage ships in the target arrays of the two underwater shots. Prior to these activities, USS ARIKARA received an undocumented amount of fallout following the detonations of Shot FIR on May 12 and Shot KOA on May 13. Following Shot WAHOO on May 16, personnel from USS ARIKARA decontaminated the target ship FULLAM by hosing it down and monitoring it for two days. After Shot UMBRELLA on June 9, the ship was assigned the mission of collecting radioactive water samples (Gladeck et al., 1982).

The fallout episodes experienced by the USS ARIKARA are listed Table 2 (DTRA, 2008, Appendix B-8). The radiation exposure rate aboard USS ARIKARA resulted from the one combined fallout event are shown in Figure 1.

Table 2. Peak Radiation Exposure Rates on USS ARIKARA during Operation HARDTACK I

Shot	Shot Date (1954) (Time)	Peak Exposure Rate (R hr^{-1})	Peak Exposure Rate Time H+ (hr)
FIR/KOA	FIR: May 12 (0550) KOA: May 13 (0630)	0.0298	58.17

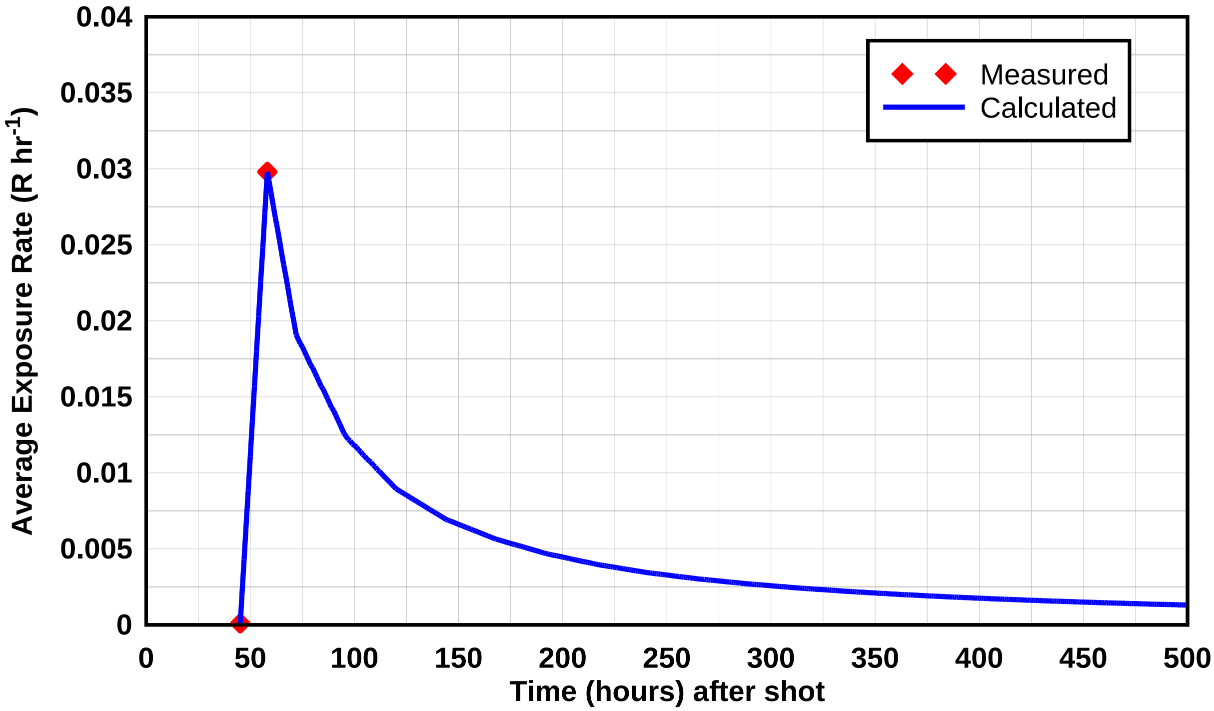

Figure 1. Average Topside Residual Radiation Exposure Rate on USS ARIKARA from Shots FIR and KOA

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the generic high-sided USS ARIKARA cohort analysis:

- An unknown portion of the USS ARIKARA crew's film badge dose was accrued during their decontamination and water sampling activities. Neither of these tasks portends a high risk of inhalation or ingestion of radioactive contaminants. Wash down systems on the target ships were activated prior to the WAHOO detonation and ran continuously post-shot for approximately 6 hours (Gladeck et al., 1982). As a result, most of the easily-lofted contaminant material would have been washed off FULLAM prior to the start of decontamination, and the wet topside environment on the target ship during decontamination would have further inhibited resuspension. Similarly, intake of contaminants via inhalation of aerosol or sea spray encountered while collecting water samples from the contaminated pool produced by UMBRELLA would have been quite small (Weitz, 1996). The potential for intake is much larger from exposure to fallout deposited on USS ARIKARA itself. Consequently, the internal dose is high-sided by assuming that all film badge dose accrued from exposure to shipboard fallout deposited during the May 14 fallout event.
- The breathing rate is increased from the default value of 1.2 $m^3\ hr^{-1}$ to 2.0 $m^3\ hr^{-1}$ for all activities. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz, et al., 2009). Other

combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average breathing rate.

- Time spent topside on USS ARIKARA is increased from the default value of 9.6 hr day^{-1} (40 percent of 24 hours) to 16 hr day^{-1}.
- A shielding factor of 0.15 (fraction transmitted) for time spent below deck is used (Thomas et al., 1983).

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure pathways for the HARDTACK I Support Ship-Based Personnel

Exposure Pathway	Basis for Exposure Pathway (High-Dose Scenario)	Additional Maximizing Factors
EXTERNAL		
Residual radiation from deposited fallout while topside during and after Operation HARDTACK I.	USS ARIKARA personnel were exposed to fallout from Shots FIR/KOA while topside from the time of deposition until 1 year beyond the start of the operation.	Assumed 16 hr day^{-1}. topside instead of 9.6 hr day^{-1}. Increased exposure rate of fallout due to FIR/KOA to 0.0298 R hr^{-1} at H+58.
Residual radiation from deposited fallout while below deck during and after Operation HARDTACK I.	USS ARIKARA personnel were exposed to fallout from Shots FIR/KOA while below deck from the time of deposition until 1 year beyond the start of the operation.	Assumed 8 hr day^{-1} below deck instead of 14.4 hr day^{-1} below. Used the highest ship shielding factor (fraction transmitted) while below deck of 0.15.
Residual radiation from deposited fallout while on shore liberty during Operation HARDTACK I.	USS ARIKARA personnel were exposed to fallout from Shots FIR/KOA, REDWOOD, and OAK during shore liberty periods at Enewetak Atoll during the operational period.	
INTERNAL		
Inhalation of resuspended fallout while topside following one fallout episode.	USS ARIKARA personnel were subjected to inhalation of resuspended fallout from Shots FIR/KOA for 100 hours following end of deposition.	Use g a high breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during shore liberty periods.	USS ARIKARA personnel were subjected to inhalation of resuspended fallout from Shots FIR/KOA, REDWOOD, and OAK during shore liberty periods at Enewetak Atoll during the operational period.	Use g a high breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}..
Incidental ingestion of contaminated soil/dust during shore liberty periods.	USS ARIKARA personnel incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots FIR/KOA, REDWOOD, and OAK during shore liberty periods at Enewetak Atoll during the operational period.	

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Reported}$	HARDTACK I start date[time] – date of first shot (YUCCA)	Apr 28, 1958[1440]
$Date_{EndOp}$	Ship departure date[time] – date ARIKARA departed test site	Aug 15, 1958[2400]
$Date_{Detacked}$	Ship detached date[time] – 1 year beyond start of operation	Apr 28, 1959[1440]
EXTERNAL DOSE		
F_{ts}	Fraction of time spent topside while aboard ship	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
SF	Shielding factor while below deck	0.15 (Thomas, 1983)
$IpeakDet_{FK}$ $TpeakDet_{FK}$	Peak exposure rate and time of peak exposure rate on USS ARIKARA due to shipboard fallout from Shots FIR/KOA	0.0298 R hr^{-1} at H+58 (Peak exposure rate selected such that reconstructed external dose equals film badge mean dose.)
$IpeakDet_{FKpi}$ $TpeakDet_{FKpi}$	Peak exposure rate and time of peak exposure rate due to fallout from Shots FIR/KOA on Parry Island, Enewetak Atoll	0.025 R hr^{-1} at H+58 (DTRA, 2008, Appendix B-8)
$IpeakDet_{RDpi}$ $TpeakDet_{RDpi}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot REDWOOD on Parry Island, Enewetak Atoll	0.0007 R hr^{-1} at H+13.5 (DTRA, 2008, Appendix B-8)
$IpeakDet_{OKpi}$ $TpeakDet_{OKpi}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot OAK on Parry Island, Enewetak Atoll	0.0025 R hr^{-1} at H+14 (DTRA, 2008, Appendix B-8)
λ_{postop}	Decay exponent for times less than H+ 4380	1.2 (DTRA, 2008, Appendix B-8)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-8)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for ship-based activities	2.0 m^3 hr^{-1}
$GSMF$	Gamma source modification factor	3.79 (mean value for fleet tug) (Weitz, 2009)
F_{ts}	Fraction of time spent topside (time exposed to resuspended fallout)	0.67 (= 16/24)
$Frac_{SL}$	Fraction of time spent on shore liberty	4 hr every 4^{th} day 0.0417 = 4/(24 × 4)
K_{Ship}	Resuspension factor for resuspension of fallout from ship surfaces	K = 10^{-5} m^{-1} (DTRA, 2010, SM ID01)
$K_{Land}(t)$	Time-dependent resuspension factor during shore liberty periods	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}\ m^{-1}$ (DTRA, 2010, SM ID01)
q_{ing}	Soil ingestion rate during shore liberty periods	500 mg day^{-1} (DTRA, 2010, SM ID01)

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
ρ_{soil}	Soil bulk density during shore liberty periods	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{InhFBE} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the HARDTACK I ship-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculations of upper-bound doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

The upper-bound doses in were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. External and Internal Doses and Upper Bounds for Operation HARDTACK I Support Ship-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	2		6	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.003	0.003	0.03
Bone Surface	0.2	0.04	2	0.4
Brain	<0.001	0.002	0.003	0.02
Breast	<0.001	0.003	0.003	0.03
Stomach Wall	<0.001	0.008	0.003	0.08
Small Intestine Wall	<0.001	0.02	0.003	0.2
Upper Large Intestine Wall	<0.001	0.08	0.003	0.8
Lower Large Intestine Wall	<0.001	0.2	0.003	2
Kidney	<0.001	0.02	0.007	0.2
Liver	0.04	0.009	0.4	0.09
Extra-Thoracic Region	0.002	0.3	0.02	3
Lung	0.004	0.3	0.04	3
Muscle	<0.001	0.003	0.003	0.03
Pancreas	<0.001	0.003	0.003	0.03
Red Marrow	0.008	0.009	0.08	0.09
Spleen	<0.001	0.02	0.003	0.2
Testes	0.003	0.002	0.03	0.02
Thymus	<0.001	0.003	0.003	0.03
Thyroid	<0.001	0.3	0.003	3
Urinary Bladder Wall	<0.001	0.02	0.003	0.2

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

Table 6. Cancer Cases not Recommended for Expedited Processing for Operation HARDTACK I Support Ship-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	9

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment – Nuclear Test Personnel Review Program. Revision 1.2*. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment - Nuclear Test Personnel Review Program. Revision 1.3/1.3a*. DTRA-SOP-10-01, January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA

Gladeck, F.R., Gould, K.G., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.A., Osborn, M.J., Shelton, C.F., Berkhouse, L., and Calhoun, F.S., 1982. *Operation HARDTACK I (1958)*. DNA 6038F (Defense Nuclear Agency, Washington, D.C.).

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11 (Science Applications International Corporation, McLean, VA, and Defense Threat Reduction Agency, Fort Belvoir, VA).

Thomas, C., Stuart, J., Goetz, J., and Klemm, J., 1983, *Analysis of Radiation Exposure for Naval Personnel at Operation IVY*. DNA TR-82-98, Defense Nuclear Agency, Washington, DC, March 15

Weitz, R. L., 1996. *Internal Dose from Sea Aerosol Intake*. Memorandum, Science Applications International Corporation, McLean, VA.

Weitz, R.L., 2009. *Formulation of the Gamma Source Modification Factor (GSMF) for Ship-based Applications*. NTPR-TM-09-04 (Defense Threat Reduction Agency, Washington, D.C.)

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation HARDTACK I Land-Based Personnel

November 2011

Important Note

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Expedited Processing Group: Operation HARDTACK I Land-Based Personnel

1. Description of the Expedited Processing Group

The HARDTACK I Land-Based Personnel Expedited Participant Group (EPG) consists of approximately 7,000 personnel assigned to the units present at the Enewetak Proving Ground to include Enewetak Island, Parry Island, Enue Island, Ugelang Atoll, Utirik Atoll, Wotho Atoll, Rongelap Atoll, and Kwajalein Atoll.

Operation HARDTACK I was a series of 35 atmospheric nuclear weapon tests conducted in the Pacific Ocean from April 28 to August 18, 1958 and is described in Gladeck et al., (1982) and DTRA (2008, Appendix B-8). The list of units involved in HARDTACK I is listed in Table 1 below (Gladeck et al., 1982).

Table 1. Operation HARDTACK I Land-Based Units

Unit	Location	Size
Task Group 7.1	Enewetak Atoll	811
Task Group 7.2 Administrative Detachment	Enewetak Atoll	532
Task Group 7.2 Operations Detachment	Enewetak Atoll	404
1st Provisional Military Policy	Enewetak and Bikini	141
Bikini Boat Pool Element	Eneu Island	227
Task Group 7.3 Boat Pool Operation (Enewetak)	Enewetak Atoll	209
Task Group 7.3 Special Projects Unit	Enewetak Island	164
Explosive Ordinance Disposal Unit 1	Enewetak Island	6
Patrol Squadron 22	Kwajalein Island	154
Patrol Squadron 28	Kwajalein Island	378
Kwajalein Naval Air Station	Kwajalein Island	22
4925th Test Group	Enewetak Island	62
4950 th Test Group	Enewetak Island	90
4926 th Test Squadron	Enewetak Island	167
4951st Test Squadron	Enewetak Island	430
4952nd Test Squadron	Enewetak Island	352
HQ USAF	Enewetak Island	20
HQ and Pacific Command, Military Air Transport Service)	Enewetak Island	10
Military Air Transport Service Terminal	Enewetak Island	1011

Table 1. Operation HARDTACK I Land-Based Units (cont.)

Unit	Location	Size
HQ Air Force Weather Service	Enewetak Atoll, Kwajalein, and Weather Islands	21
6th Weather Squadron	Enewetak Atoll	142
57th Weather Reconnaissance Squadron	Enewetak Atoll	388
HQ Airways and Air Communication Service	Enewetak Atoll	7
1253rd Airways and Air Communication Service Squadron	Enewetak Atoll	402
1352nd Photographic Squadron	Enewetak Atoll	26
1371st Map and Charting Squadron	Enewetak Atoll	83
64th Air Reconnaissance Squadron	Enewetak Atoll	168
24th Helicopter Squadron	Enewetak Atoll	120
4080th Strategic Reconnaissance Wing	Enewetak Atoll	130
Others	Unknown	28
	Total	6705

The following individuals are excluded from expedited processing under this EPG:

- Personnel who resided on Japtan Island during Operation HARDTACK I (DTRA, 2008, Appendix B-8).
- Personnel assigned to Johnston Island.

2. Basis of Dose Analysis for HARDTACK I Land-Based Personnel

To estimate EPG doses for all Operation HARDTACK I Land-Based Personnel, an exposure scenario was developed based on activities of the cohort group that received the highest dose from exposure to external radiation and corresponding internal doses. This cohort is referred to as the “highest-dose cohort”. Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a “highest-dose cohort” because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of the Task Group 7.1 Personnel on Parry Island form the basis for the highest-dose cohort scenario (DTRA, 2008, Appendix B-8) for the two primary reasons:

- This group received the largest external gamma dose from residual radiation of all Operation HARDTACK I land-based personnel except for those individuals assigned to Japtan Island.
- The activities of this group are well-documented and are representative of other HARDTACK I land-based personnel.

Several dose components and assumptions were added to the documented Task Group 7.1 Personnel on Parry Island scenario (DTRA, 2008, Appendix B-8) to produce EPG doses. The Task Group 7.1 Personnel on Parry Island is described below followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Task Group 7.1 Personnel on Parry Island

To estimate EPG doses for all military personnel assigned to islands in the Pacific Proving Ground (PPG) during Operation HARDTACK I, a generic high-sided exposure scenario was developed based on activities of TG 7.1 personnel on Parry Island. The TG 7.1island residents on Parry Island supported a variety of experiments and provided support for TG 7.1 to include Task Unit 7.1.3, DOD programs, and Task Unit 7.1.6, Radiation Safety (Gladeck et al., 1982; DTRA 2008, Appendix B-8).

TG 7.1 personnel on Parry Island were exposed to fallout from six HARDTACK I shots. However, the fallout from Shots KOA and FIR arrived at the same time (Gladeck et al., 1982; DTRA, 2008, Appendix B-8). During the fallout episode for FIR/KOA, it is assumed that 40% of the fallout is due to Shot FIR and 60% of the fallout is due to Shot KOA. Table 2 lists the fallout episodes on Parry Island. Figure 1 - Figure 5 are of the exposure rates on Parry Island due to each fallout event (DTRA, 2008, Appendix B-8).

Table 2. Fallout Episodes on Parry Island

Shot	Peak Exposure Rate Time (H+)	Peak Exposure Rate (R/hr)
FIR/KOA	58	0.025
REDWOOD	13.5	0.0003
OAK	14	0.002
POPLAR	12.25	0.0015
PISONIA	3.8	0.034

Figure 1. External Radiation Exposure Rate on Parry Island from Shots FIR/KOA

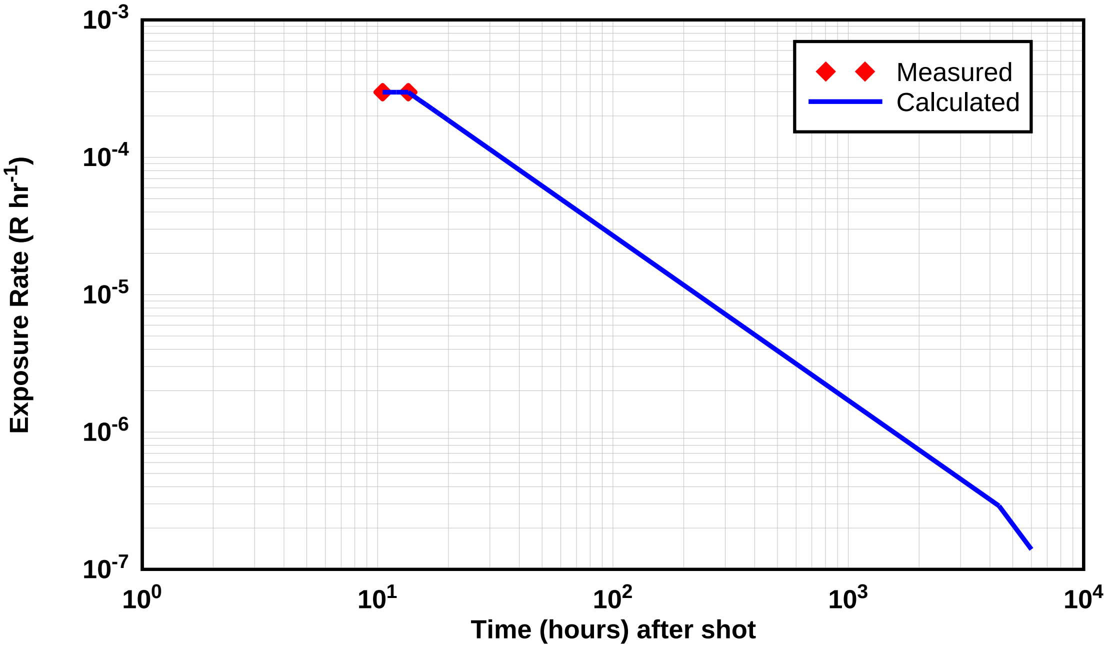

Figure 2. External Radiation Exposure Rate on Parry Island from Shot REDWOOD

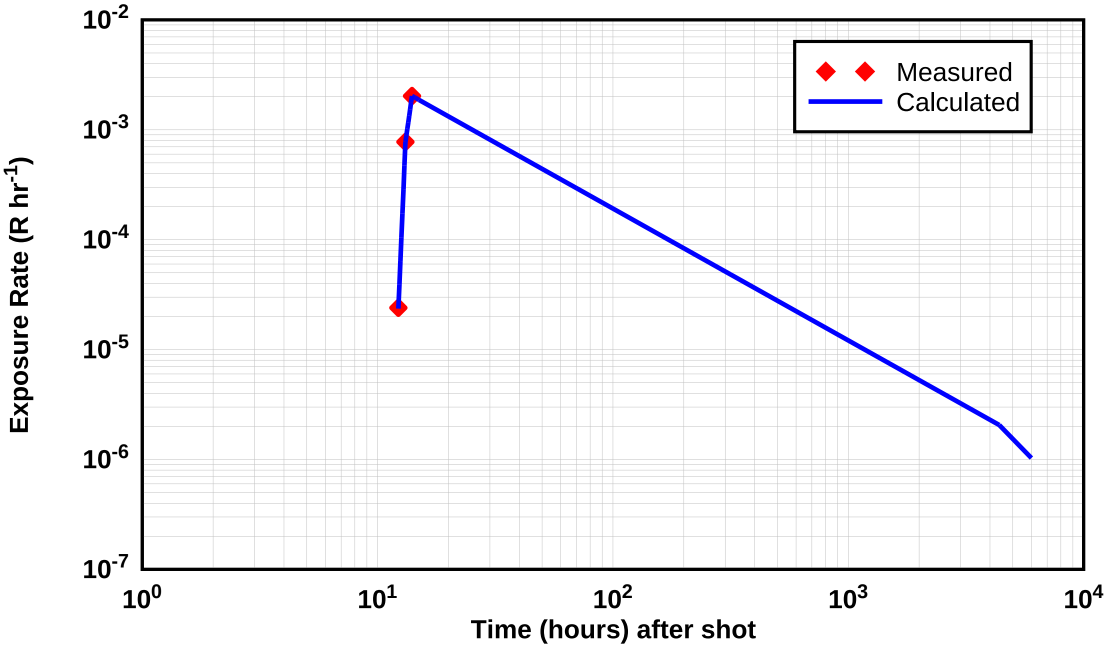

Figure 3. External Radiation Exposure Rate on Parry Island from Shot OAK

Figure 4. External Radiation Exposure Rate on Parry Island from Shot POPLAR

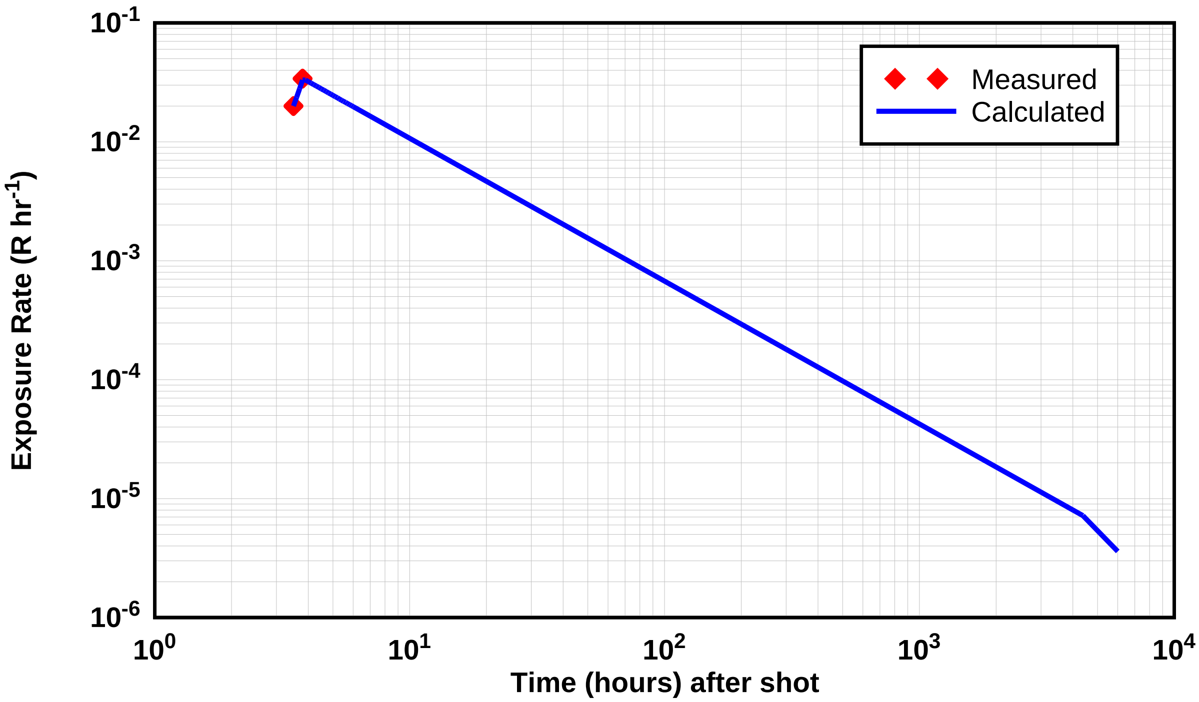

Figure 5. External Radiation Exposure Rate on Parry Island from Shot PISONIA

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Task Group 7.1 cohort analysis:

- The period of assignment was assumed to be from January 31, 1958 to July 6, 1959. This is longer than any known participant actually stayed at Enewetak Atoll, Bikini Atoll, or Kwajalein Atoll.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1} assuming that 8 hours were spent indoors for sleeping, cleaning and eating.
- It is assumed that 100 percent of this time spent indoors was spent in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The EPG members are assumed to be outdoors during descending fallout and the fallout is considered light enough so that daily duty routines were not altered (Thomas et al., 1984).
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al. 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure Pathways for HARDTACK I Land-Based Personnel

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from Operation REDWING	Task Group 7.1 members were exposed to fallout from Operation REDWING	The time outside was 16 hr day^{-1} instead of 14.4 hr day^{-1}. Protection factor was high-sided at 1.5
Residual radiation from six shots during Operation HARDTACK I	Task Group 7.1 members were exposed to fallout from Shots FIR/KOA, REDWOOD, OAK, POPLAR, and PISONIA. .	The number of hours spent outside was increased from 14.4 to 16 hr day^{-1}. Protection factor was high-sided at 1.5
INTERNAL		
Inhalation of resuspended fallout from Operation REDWING shots	Task Group 7.1 members were subjected to inhalation of resuspended fallout from Operation REDWING shots.	Used a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout from six shots during Operation HARDTACK I	Task Group 7.1 members were subjected to inhalation of resuspended fallout from Shots FIR/KOA, REDWOOD, OAK, POPLAR, and PISONIA.	Used a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from Operation REDWING shots	Task Group 7.1 members incurred doses from incidental ingestion of soil and dust contaminated with fallout from Operation REDWING shots.	
Incidental ingestion of contaminated soil/dust from six shots during Operation HARDTACK I	Task Group 7.1 members incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots FIR/KOA, REDWOOD, OAK, POPLAR and PISONIA.	

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$-	Parry Island arrival date	31 Jan 1958 [1200]
$Date_{StartOp}$	HARDTACK I start date[time]	12 May 1958[0550]
$Date_{EndOp}$	HARDTACK I end date[time]	18 Aug 1958[2400]
$Date_{Departed}$	Parry Island departure date[time]	18 Aug 1959[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Parry Island	0.67 (= 16/24)
F_B	Film-badge conversion factor	0.7 rem R^{-1} (SM ED02 of DTRA, 2010)
PF_t	Protection factor while indoors, assumed inside a tent	1.5 (SM ED02 of DTRA, 2010)
$IpeakDet_{FK}$ $TpeakDet_{FK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot FIR/KOA	0.025 R hr^{-1} at H+58 (DTRA, 2008, Appendix B-8)
$IpeakDet_{RD}$ $TpeakDet_{RD}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot REDWOOD	0.0003 R hr^{-1} at H+13.5 (DTRA, 2008, Appendix B-8)
$IpeakDet_{OK}$ $TpeakDet_{OK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot OAK	0.002 R hr^{-1} at H+14 (DTRA, 2008, Appendix B-8)
$IpeakDet_{PO}$ $TpeakDet_{PO}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot POPLAR	0.0015 R hr^{-1} at H+12.25 (DTRA, 2008, Appendix B-8)
$IpeakDet_{PI}$ $TpeakDet_{PI}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot PISONIA	0.034 R hr^{-1} at H+3.8 (DTRA, 2008, Appendix B-8)
λ_{postop}	Decay exponent for times less than H+ 4380	1.2 (DTRA, 2008, Appendix B-8)
λ_{6mon}	Decay exponent for times greater than H+4380	2.2 (DTRA, 2008, Appendix B-8)
$DoseDet_{Pre}$	External gamma dose due to fallout from Operation REDWING residual radiation	0.022 rem (Mason, 2009)
INTERNAL DOSE		
H_{min}	Initial cloud debris height	10,000 m
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
Thick	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
$Doseint_{Pre}$	Internal dose due to fallout from Operation REDWING residual radiation	per Mason, 2009 Used a breathing rate of 2 m^3 hr^{-1} (instead of 1.2 m^3 hr^{-1}).
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
DCF_{Inhfbe} DCF_{Inhact} DCF_{Ing}	Fallout inhalation (film-badge equivalent and activity) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the HARDTACK I land-based personnel are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 5. External and Internal Doses and Upper Bounds for Operation HARDTACK I Land-Based Personnel

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	3		8	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.02	0.02	0.2
Bone Surface	2	0.3	12	3
Brain	0.002	0.007	0.02	0.07
Breast	0.002	0.01	0.02	0.2
Stomach Wall	0.002	0.05	0.02	0.4
Small Intestine Wall	0.002	0.09	0.02	0.8
Upper Large Intestine Wall	0.002	0.4	0.02	4
Lower Large Intestine Wall	0.002	0.9	0.02	8
Kidney	0.006	0.06	0.06	0.6
Liver	0.3	0.06	3	0.6
Extra-Thoracic Region	0.02	2	0.2	12
Lung	0.03	1	0.3	11
Muscle	0.002	0.02	0.02	0.2
Pancreas	0.002	0.02	0.02	0.2
Red Marrow	0.06	0.05	0.6	0.5
Spleen	0.002	0.05	0.02	0.5
Testes	0.02	0.008	0.2	0.08
Thymus	0.002	0.02	0.02	0.2
Thyroid	0.002	1.1	0.02	11
Urinary Bladder Wall	0.002	0.06	0.02	0.6

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure (DTRA, 2010, SM ED02).

The upper-bound doses in Table 5 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 6. Cancer Cases not Recommended for Expedited Processing for Operation HARDTACK I Land-Based Personnel

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Liver	Liver	12
Thyroid	Thyroid	18
Total EPG upper-bound dose below but close to the screening dose		
Bone	Bone Surface	23
Bile Duct	Liver	12
Gall Bladder	Liver	12

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Gladeck, F.R., Gould, K.G., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.A., Osborn, M.J., Shelton, C.F., Berkhouse, L., and Calhoun, F.S., 1982. *Operation HARDTACK I (1958)*. DNA 6038F, Defense Nuclear Agency, Washington, D.C. December 1.

Mason, C, 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations*. NTPR-TM-09-02, Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Thomas, C., Goetz, J., Klemm, J., and Weitz, R., 1984. *Analysis of Radiation Exposure for Naval Personnel at Operation CASTLE*. DNA-TR-84-6, Defense Nuclear Agency, Washington, DC. February 28.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November..

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation HARDTACK I
Non-Exposed Support Ship-Based Personnel

November 2011

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Expedited Processing Group: Operation HARDTACK I Non-Exposed Support Ship-Based Personnel

1. Description of the Expedited Processing Group

The HARDTACK I Non-Exposed Support Ship-Based Personnel Expedited Processing Group (EPG) consists of the crews of ships that were present either at the Enewetak Proving Ground or Johnston Island during the operation, were present as a direct consequence of the operation, or who were issued film badges in anticipation of supporting HARDTACK I, but for which there was no potential for external or internal exposure to radiation. Ships included in this EPG are listed in Table 1 (Gladeck et al., 1982).

Excluded from this EPG are two crew members of USS COMSTOCK who received non-zero readings on film badges issued to them (see discussion below).

Table 1. Non-Exposed Naval Ships that Participated in Operation HARDTACK

Ship	Location	Arrival (1958)	Departure (1958)	Size
USS COGSWELL (DD 651)	Johnston Island	July 10	August 1	238
USS COMSTOCK (LSD 19)	Enewetak Atoll Pre-Operation	January 20	May 1	230
USS EPPERSON (DDE 719)	Johnston Island	August 7	August 12	~300
USS HITCHITI (ATF 103)	Johnston Island	July 30,	August 2	71
USS SILVERSTEIN (DE 534)	Enewetak to Guam Cruise Post-Operation	August 31	September 13	~230
USS TILLAMOOK (ATA 192)	Johnston Island	July 28	August 7	~20
USS TORTUGA (LSD 26)	Enewetak Atoll Pre-Operation	March 1	April 14	326
			Total	~1,400

2. Basis of Dose Analysis for HARDTACK I Non-Exposed Support Ship Crew

Four ships (USS COGSWELL, USS EPPERSON, USS HITCHITI, and USS TILLAMOOK) operated solely in the vicinity of Johnston Island while supporting HARDTACK I. There was no potential for exposure at that location except for those ships specifically designated to assist in the recovery of rocket nosecones. These four ships were not assigned recovery duties, and their crews were not issued film badges (Gladeck et al., 1982).

USS COMSTOCK primarily participated in pre-operational activities in the Enewetak Proving Ground and at Johnston Island. The ship arrived in the test area (Enewetak) in January 1958 and departed the test area (Johnston Island) three days before the first shot of the operation (YUCCA). COMSTOCK returned to the test area for a single day (Johnston Island on May 1, three months before the first of the two high altitude shots launched from that site), then departed for the U.S. West Coast. The entire crew of 230 personnel was issued film badges; all but two recorded zero dose. The two outliers registered small doses on their badges, almost certainly from non-radiological environmental conditions (NRC, 1989). Nevertheless, the two recipients of the non-zero badge readings are excluded from the EPG (Gladeck et al., 1982).

USS SILVERSTEIN did not participate in any of the HARDTACK I shots, but its mission derived from the operation. The ship arrived at Enewetak Atoll 13 days after the last detonation of the series and immediately departed on a two-week round trip to Guam. The USS SILVERSTEIN collected water samples approximately every 250 nmi along its route to survey the dispersal of radioactivity in the ocean. The crew was not badged, apparently due to lack of potential for exposure (Gladeck et al., 1982). Any radioactivity found in water samples drawn at these times and distances would have been so dilute as to preclude measureable exposure.

USS TORTUGA participated only in the pre-operational phase of HARDTACK I, departing the test area two weeks before the first shot of the series. The ship's crew was issued film badges because it was initially anticipated that TORTUGA would play a much more significant role in the operation. None of the issued badges recorded an exposure (Gladeck et al., 1982).

3. Summary of EPG Doses and Upper Bounds

For the reasons detailed above, there was no potential for exposure for all members of this EPG.

4. References

Gladeck, F.R., Gould, K.G., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.A., Osborn, M.J., Shelton, C.F., Berkhouse, L., and Calhoun, F.S., 1982. *Operation HARDTACK I (1958)*. DNA 6038F (Defense Nuclear Agency, Washington, D.C.).

NRC (National Research Council), 1989. "*Film Badge Dosimetry in Atmospheric Nuclear Tests*". (National Academy Press, Washington, D.C.).

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation DOMINIC I Personnel

November 2011

<u>Important Note</u>

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Expedited Processing Group: Operation DOMINIC I Personnel

1. Description of the Expedited Processing Group

The DOMINIC I Expedited Processing Participant Group (EPG) consists of all individuals who participated in Operation DOMINIC I to include ship- and island-based personnel. Individuals with exposure types identified below as exclusions are processed separately.

Operation DOMINIC I was a series of 36 atmospheric nuclear tests held in the Pacific Ocean during 1962. The tests, which included high-altitude airdrops, missile launched detonations, and underwater tests, were conducted by Joint Task Force Eight (JTF 8). Details of the various tests, types of nuclear devices, and locations can be found in Berkhouse et al. (1983) and DTRA, Appendix B-10 (2008).

Approximately 28,000 personnel who manned 90 ships (78 U.S. Navy, six Military Sea Transport Service, three Commercial, two U.S. Coast Guard, and one U.S. Army), two island facilities, and 136 aircraft participated in DOMINIC I. The majority of the personnel were stationed at Christmas and Johnston Islands or aboard Navy ships. More than 80 percent of the participants were military personnel. Of the military personnel, about 81 percent were in the Navy, 13 percent in the Air Force, and the rest in the Army and Marine Corps (DTRA, 2008, Appendix B-10).

The following individuals and units are excluded from expedited processing under this EPG:

- Crewmembers of USS SIOUX (ATF 75), USC&GSS PIONEER (OSS-31), and USS MONTICELLO (LSD-35) during Shot SWORDFISH.
- Crewmember of any ship involved in the recovery/handling of radioactively contaminated instrumented pods and rocket nose cones associated with successful THOR missile and rocket launches.
- Crewmembers of any ship involved in recovery/decontamination operations after any of the THOR missile incidents during Shots BLUEGILL, STARFISH, BLUEGILL PRIME.
- Crewmembers of any ship involved in recovery, servicing, or boarding of target rafts after airdrop shots,
- Crewmembers of any ship involved in the recovery/handling of other contaminated with radioactive materials due to neutron activation.

2. Basis of Dose Analysis for Operation DOMINIC I Personnel

The nuclear tests during Operation DOMINIC I were conducted in a manner to limit radiation exposures of test participants. At Christmas Island, tests were airdrops from B-52 aircraft and detonations occurred at elevations between 2610 and 15995 feet above sea level. The devices were detonated at sufficient altitudes that the fireballs did not touch the ocean surface and thus, no local fallout was formed. The closest ship to the shots was between 23 and 30 nautical miles (nmi) from surface zero (Berkhouse et al., 1983). Five of the tests at Johnston Atoll were also

B-52 airdrops with detonations occurring at high elevations. The nearest ship to surface zero of the five Johnston Island airbursts was 30 nmi. For Shot SWORDFISH, an underwater test, the nearest ship was 2 nmi from the projected surface zero and was upwind. Individuals on ships who were close enough to contaminated water and had the potential for exposure to external radiation are excluded from this EPG (see list of excluded individuals in Section 1 above). For the rocket-launched shots that were the FISHBOWL portion of DOMINIC I on Johnston Island, any participants who were possibly exposed to ionizing radiation are excluded from this EPG and all of the exposures were due to the clean up of debris from failed shots (Berkhouse et al., 1983).

Of the DOMINIC I participants, about 25,000 military and civilian personnel were issued film badges. About 3,000 participants who were manning radiation detection instruments or conducting experiments on islands that were located hundreds of kilometers from the tests were not badged. About 43,000 film badges were used. Two dosimetry sections in the Pacific processed about 33,000 badges. The remaining film badges, numbering approximately 10,000 were processed at the Nevada Test Site radiological safety laboratory after the end of DOMINIC I.

Many of the film badges were worn for long periods of time and experienced damage due to heat, humidity, light leaks, and emulsion aging that caused increased optical density and, thus, recorded incorrect external dose results (NRC, 1989). Many of the dosimeter films from badges worn by DOMINIC I personnel had water damage. In addition to water damage, the films from badges had a high incidence of damage due to light leaks from breaches in the plastic covering of the badge. Such light damage occurred in film badges that were worn for long periods, which appeared to correlate with a higher frequency of emulsion and/or process damage. Many films with long wear periods also exhibited spurious “filter images” due to background radiation (without appropriate controls) and/or pressure from the lead filter strip (NRC, 1989; SAIC and NST - LLC, 1989–2006; Perkins and Hammond, 1980). The lack of appropriate background subtraction and the inadequate screening of dose results were the principal reasons for the positive doses assigned to individuals who had no potential for exposure to any radiation (NRC, 1989).

Many of the film badge results above zero are not indicative of true external radiation exposure. Not all of the optical intensity of the film badges can be attributed to ionizing radiation exposure. However, the amount of increased optical density due to radiation exposure compared to environmental damage cannot be easily quantified (Berkhouse et al., 1983).

For potentially damaged film badges, the NTPR standard operating procedures (DTRA, 2010) recommend that, if possible, individual film badges are evaluated and results reassessed. However, for the purpose of expedited processing, there is no need to expend resources to prove or disprove a film badge dose for individuals who had no potential for exposure to any ionizing radiation but had non-zero film badge readings. For these individuals, benefit of the doubt principles are used and the recorded film badge dose is assigned as an upper bound external dose (DTRA, 2010). No internal doses are assigned as there was no potential for intake of contaminated materials from any source for members of this group (Berkhouse et al., 1983).

3. Summary of EPG Doses and Upper Bounds

The EPG external dose for DOMINIC I Personnel EPG is summarized in Table 1. The maximized upper bound external gamma dose for a member of this EPG is assumed to be the film badge dose assigned from the veteran's records. There was no potential for exposure to internally-deposited radionuclides for this group. For members with no recorded film badge doses, their dose assessment should report that "the veteran had no potential for exposure to external or internal radiation."

Table 1. External and Internal Doses and Upper-Bounds for DOMINIC I Personnel

<table>
<tr><th>External Doses</th><th colspan="2">EPG Dose (rem)</th><th colspan="2">Upper-Bound EPG Dose (rem)</th></tr>
<tr><td>Residual gamma radiation for participants with film badge records</td><td colspan="2">n/a</td><td colspan="2">Film badge dose</td></tr>
<tr><td>Residual gamma radiation for participants with no film badge records</td><td colspan="4">No potential for exposure to external radiation</td></tr>
<tr><td>Initial Gamma*</td><td colspan="2">-</td><td colspan="2">-</td></tr>
<tr><td>Neutron*</td><td colspan="2">-</td><td colspan="2">-</td></tr>
<tr><td colspan="5"></td></tr>
<tr><th rowspan="2">Internal Doses for NTPR Standard Organs</th><th colspan="2">EPG Dose (rem)</th><th colspan="2">Upper-Bound EPG Dose (rem)</th></tr>
<tr><th>Alpha</th><th>Beta + Gamma</th><th>Alpha</th><th>Beta + Gamma</th></tr>
<tr><td>All Organs</td><td colspan="4">There was no potential for exposure to internally-deposited radionuclides for this group.</td></tr>
</table>

* Initial gamma and neutron doses are estimated separately based on the actual participant's exposure in accordance with NTPR standard operating procedure SM ED02 (DTRA, 2010).

4. References

Berkhouse, L. Davis, S.E., Gladeck, F.R., Hallowell, J.H., Jones, C.B., Martin, E.J., Miller, R.A., McMullan, F.W., Osborne, M.J., 1983. *Operation DOMINIC I 1962.* DNA 6040F, Defense Nuclear Agency, Washington, DC. February 1.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011, A*n Expedited Approach to NTPR Radiation Dose Assessments*. TBD, Defense Threat Reduction Agency, Fort Belvoir, VA.TBD.

NRC (National Research Council), 1989. Film Badge Dosimetry in Atmospheric Nuclear Tests. National Academy Press, Washington, D.C.

Perkins, W. W., and Hammond, R. R., 1980. *Navy Film Badge Review: DOMINIC, Navy Nuclear Test Personnel Review Program*. NOSC TR 583, Naval Ocean Systems Center. May 28.

SAIC (Science Applications International Corporation) and NST - LLC (National Securities Technologies LLC), 1989–2006. *Evaluations of dosimeter films conducted from about 1989 to 2006*. Las Vegas, Nevada.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Post-SANDSTONE Enewetak Atoll

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group:
Post-SANDSTONE Enewetak Atoll

1. Description of the Expedited Processing Group

The Post-SANDSTONE-Enewetak Atoll Expedited Processing Group (EPG) consists of approximately 1,889 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak, Japtan, and Parry Islands) during the period between June 1, 1948 and April 8, 1951 (Mason, 2009).

Operation SANDSTONE is described in Berkhouse et al (1983) and DTRA (2008, Appendix B-2). After the formal end of the operation, individuals remained on Enewetak Atoll to serve as the garrison for the Pacific Proving Ground. There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for Post-SANDSTONE Enewetak Atoll

To estimate EPG doses for Post-SANDSTONE Enewetak Atoll personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort."

For this EPG, Post-SANDSTONE personnel assigned to Enewetak Island who arrived on June 1, 1948 are identified as the generic highest-dose cohort. Post-SANDSTONE personnel assigned to Enewetak Island are representative of personnel on Enewetak Atoll who received the highest dose for post-SANDSTONE personnel during the interval between SANDSTONE and Operation GREENHOUSE.

Post-SANDSTONE personnel assigned to Enewetak Island form an adequate basis of the generic highest-dose cohort scenario (Mason, 2009; DTRA, 2008, Appendix B-2) for this EPG for two primary reasons:

- The group was assigned to Enewetak Atoll similar to most inter-operational personnel.
- The group did not have any involvement in unique exposure activities.

As explained below, several dose components and assumptions were added to the documented Enewetak Island residents' scenario to produce EPG doses. The Post-SANDSTONE personnel assigned to Enewetak Island scenario is described directly below, followed by a description of the dose components and assumptions.

3. Highest-Dose Cohort Scenario: Post-SANDSTONE Personnel Assigned to Enewetak Island

To estimate EPG doses for all military personnel assigned to Enewetak Atoll during the Post-SANDSTONE inter-operational period, a generic high-sided exposure scenario was developed based on activities of Post-SANDSTONE personnel assigned to Enewetak Island.

Post-SANDSTONE personnel assigned to Enewetak Island had no involvement in unique exposure activities, so their only source of exposure was fallout from Operation SANDSTONE shots that were conducted before their assumed arrival. The SANDSTONE shots and the resulting fallout exposure rates at Enewetak Island are shown in Table 1. Based on these exposure rates, decayed to the end of the operation and then one year beyond, the Post-SANDSTONE personnel assigned to Enewetak Island who lived on Enewetak Island accrued external doses from fallout deposited on Enewetak Island while outside and while indoors. Post-SANDSTONE personnel assigned to Enewetak Island also received internal doses while outdoors during the same period from inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust (DTRA, 2008, Appendix B-2).

Table 1. Operation SANDSTONE Detonations that Affected Enewetak Island

Shot	Time and Date of Detonation	Peak Exposure Rate (R hr^{-1})	Peak Time (H+hr)
XRAY	April 15, 1948 at 0617	0.0001	48
YOKE	May 1 1948 at 0609	0.0003	54
ZEBRA	May 15, 1948 at 0604	0.00004	144

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Enewetak Atoll resident cohort analysis:

- The period of exposure to Enewetak Island is assumed to be from June 1, 1948 to May 31, 1949. This start date is the first of the month after the last SANDSTONE Shot. The end date corresponds to one year later. The internal doses were calculated through April 8, 1951 (Mason, 2009).
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning, and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz, et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the Post-SANDSTONE Enewetak Atoll Residents

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from three shots of Operation SANDSTONE	Post-SANDSTONE Personnel assigned to Enewetak Island were exposed to residual radiation fallout from Shots XRAY, YOKE, and ZEBRA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of resuspended fallout from three fallout episodes	Post-SANDSTONE Personnel assigned to Enewetak Island were subjected to inhalation of resuspended fallout from Shots XRAY, YOKE, and ZEBRA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from three fallout episodes	Post-SANDSTONE Personnel assigned to Enewetak Island incurred doses from incidental ingestion of soil and dust contaminated with fallout from XRAY, YOKE, and ZEBRA.	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartPSS}$	Post-SANDSTONE start date[time]	1 June 1948[0000]
$Date_{EndPSS}$	Post-SANDSTONE end date[time]	31 May 1949[2400]
$Date_{Departed}$	Enewetak Island departure date[time]	31 May 1949[2400]
$Date_{Departedint}$	Enewetak Island departure date for internal dose calculations [time]	8 April 1952[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Island	0.67 (= 16/24)
PF_{tent}	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
F_B	Film badge conversion factor	0.7 (DTRA, 2010, SM ED02)
$\lambda_{postopXY}$	Decay exponent for post-operation- Shot XRAY	1.2 (DTRA, 2008, Appendix B-2)
$\lambda_{postopYK}$	Decay exponent for post-operation- Shot YOKE	1.0 (DTRA, 2008, Appendix B-2)
$\lambda_{postopZE}$	Decay exponent for post-operation- Shot ZEBRA	1.2 (DTRA, 2008, Appendix B-2)
λ_{6mon}	Decay exponent for times greater than H+6 months	2.2 (DTRA, 2008, Appendix B-2)
$IpeakDet_{XY}$ $TpeakDet_{XY}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot XRAY	0.0001 R hr^{-1} at H+48 (DTRA, 2008, Appendix B-2)
$IpeakDet_{YK}$ $TpeakDet_{YK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot YOKE	0.0003 R hr^{-1} at H+ 54 (DTRA, 2008, Appendix B-2)
$IpeakDet_{ZE}$ $TpeakDet_{ZE}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZEBRA	0.00004 R hr^{-1} at H+144 (DTRA, 2008, Appendix B-2)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Soil thickness	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{Ing}	Fallout inhalation (film-badge equivalent) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-SANDSTONE Enewetak Atoll are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Post-SANDSTONE Enewetak Atoll

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	0.05		0.2	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	<0.001	<0.001	0.002
Bone Surface	0.009	0.003	0.08	0.02
Brain	<0.001	<0.001	<0.001	<0.001
Breast	<0.001	<0.001	<0.001	0.002
Stomach Wall	<0.001	<0.001	<0.001	0.002
Small Intestine Wall	<0.001	<0.001	<0.001	0.002
Upper Large Intestine Wall	<0.001	0.002	<0.001	0.009
Lower Large Intestine Wall	<0.001	0.005	<0.001	0.03
Kidney	<0.001	<0.001	<0.001	<0.001
Liver	0.002	<0.001	0.02	0.003
Extra-Thoracic Region	<0.001	0.003	<0.001	0.03
Lung	<0.001	0.02	0.002	0.2
Muscle	<0.001	<0.001	<0.001	<0.001
Pancreas	<0.001	<0.001	<0.001	<0.001
Red Marrow	<0.001	0.001	0.004	0.005
Spleen	<0.001	<0.001	<0.001	<0.001
Testes	<0.001	<0.001	0.002	<0.001
Thymus	<0.001	<0.001	<0.001	0.002
Thyroid	<0.001	0.002	<0.001	0.009
Urinary Bladder Wall	<0.001	<0.001	<0.001	0.001

* NPE = no potential for exposure.
† Organ doses were obtained from Mason (2009) and adjusted to incorporate EPG assumptions.

6. References

Berkhouse, L., Davis, S.E., Gladeck, F.R., Hallowell, J.H., Jones, C.B., Martin, E.J. , McMullan, F.W., Rogers, W.E., and Osborne, M.J., 1983. *Operation SANDSTONE: 1948, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review*. DNA 6033F, Defense Nuclear Agency, Washington, DC. Dec 19.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations*. NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R.L. and Egbert, S.D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Post-GREENHOUSE Enewetak Atoll

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

Expedited Processing Group: Post-GREENHOUSE Enewetak Atoll

1. Description of the Expedited Processing Group

The Post-GREENHOUSE-Enewetak Atoll Expedited Processing Group (EPG) consists of approximately 2,564 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak, Japtan, and Parry Islands) during the period between June 1, 1951 and November 1, 1952 (Mason, 2009).

Operation GREENHOUSE is described in Berkhouse et al. (1983) and DTRA (2008, Appendix B-3. After the formal end of the operation, individuals remained on Enewetak Atoll to serve as the garrison for the Pacific Proving Ground.

There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for Post-GREENHOUSE Enewetak Atoll

To estimate EPG doses for Post-GREENHOUSE Enewetak Atoll personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort."

For this EPG, Post-GREENHOUSE personnel assigned to Parry Island who arrived on June 1, 1951 are identified as the generic highest-dose cohort. Post-GREENHOUSE personnel assigned to Parry Island are representative of personnel on Enewetak Atoll who received the highest dose for post-GREENHOUSE personnel during the interval between GREENHOUSE and Operation IVY.

Post-GREENHOUSE personnel assigned to Parry Island form an adequate basis of the generic highest-dose cohort scenario Mason, 2009 and DTRA, 2008, Appendix B-3) for this EPG for two primary reasons:

- The group was assigned to Enewetak Atoll similar to most inter-operational personnel.
- The group did not have any involvement in unique exposure activites.

For use with the EPG, the generic highest-dose cohort scenario is augmented with additional dose components and assumptions. The basic scenario of participation and radiation exposure of the Post-GREENHOUSE personnel assigned to Parry Island scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Post-GREENHOUSE Personnel Assigned to Parry Island

To estimate EPG doses for all military personnel assigned to Enewetak Atoll during the Post-GREENHOUSE inter-operational period, a generic high-sided exposure scenario was developed based on activities of Post-GREENHOUSE personnel assigned to Parry Island.

Post-GREENHOUSE personnel assigned to Parry Island had no involvement in unique exposure activities, so their only source of exposure was fallout from Operation GREENHOUSE shots that were conducted before their assumed arrival. The GREENHOUSE shots and the resulting fallout exposure rates at Parry Island are shown in Table 1. Based on these exposure rates, decayed to the end of the operation and then one year beyond, the Post-GREENHOUSE personnel assigned to Parry Island who lived on Parry Island accrued external doses from fallout deposited on Parry Island while outside and while indoors. Post-GREENHOUSE personnel assigned to Parry Island personnel also received internal doses while outdoors during the same period from inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust (DTRA, 2008, Appendix B-3).

Table 1. Operation GREENHOUSE Detonations that Affected Parry Island

Shot	Time and Date of Detonation	Peak Exposure Rate ($R\ hr^{-1}$)	Peak Time (H+hr)
DOG	April 8, 1951 at 0634	0.083	6
EASY	April 21 1951 at 0627	0.001	24
ITEM	May 25, 1951 at 0617	0.118	14

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Parry Island resident cohort analysis:

- The period of exposure to Parry Island is assumed to be from June 1, 1951 to May 31, 1952. This start date is the first of the month after the last GREENHOUSE Shot. The end date corresponds to one year later. The internal dose calculations were through March 1, 1954 the start of Operation CASTLE.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning, and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 $m^3\ hr^{-1}$. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other

combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

- The exposure rate for Shot ITEM fallout for Enewetak Island of 0.118 R hr^{-1} at H+14 is used instead of the 0.0885 R hr^{-1}.

Exposure pathways for the EPG scenario are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the Post-GREENHOUSE Enewetak Atoll Residents

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from three shots of Operation GREENOUSE	Post-GREENHOUSE Personnel assigned to Parry Island were exposed to fallout from Shots DOG, EASY, and ITEM.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of resuspended fallout from three fallout episodes	Post-GREENHOUSE Personnel assigned to Parry Island were subjected to inhalation of resuspended fallout from Shots DOG, EASY, and ITEM.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from three fallout episodes	Post-GREENHOUSE Personnel assigned to Parry Island incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots DOG, EASY, and ITEM.	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartPGH}$	Post-GREENHOUSE start date[time]	1 June 1951[0000]
$Date_{EndPGH}$	Post-GREENHOUSE end date[time]	31 May 1952[2400]
$Date_{Departed}$	Parry Island departure date[time]	31 May 1952[2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Parry Island	0.67 (= 16/24)
PF_{tent}	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
F_B	Film badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
$\lambda_{postopDG}$	Decay exponent for post operation- Shot DOG	1.083 (DTRA, 2008, Appendix B-3)
$\lambda_{postopES}$	Decay exponent for post operation- Shot EASY	1.2 (DTRA, 2008, Appendix B-3)
$\lambda_{postopIT}$	Decay exponent for post operation- Shot ITEM	1.2 (DTRA, 2008, Appendix B-3)
λ_{6mon}	Decay exponent for post-operation for times greater than H+6 months	2.2 (DTRA, 2008, Appendix B-3)
$Ipeak_{DG}$ $Tpeak_{DG}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot DOG	0.083 R hr^{-1} at H+6 (DTRA, 2008, Appendix B-3)
$Ipeak_{ES}$ $Tpeak_{ES}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot EASY	0.001 R hr^{-1} at H+ 24 (DTRA, 2008, Appendix B-3)
$Ipeak_{IT}$ $Tpeak_{IT}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ITEM	0.118 R hr^{-1} at H+14 (DTRA, 2008, Appendix B-3)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Soil thickness that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{Ing}	Fallout inhalation (film-badge equivalent) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-GREENHOUSE Enewetak Atoll are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Post-GREENHOUSE Enewetak Atoll Residents

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	3		8	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.007	0.004	0.06
Bone Surface	0.3	0.08	3	0.6
Brain	<0.001	0.003	0.004	0.02
Breast	<0.001	0.006	0.004	0.05
Stomach Wall	<0.001	0.01	0.004	0.07
Small Intestine Wall	<0.001	0.02	0.004	0.2
Upper Large Intestine Wall	<0.001	0.09	0.004	0.5
Lower Large Intestine Wall	<0.001	0.3	0.004	2
Kidney	0.001	0.005	0.009	0.04
Liver	0.05	0.02	0.5	0.1
Extra-Thoracic Region	0.002	0.2	0.03	2
Lung	0.005	0.7	0.05	7
Muscle	<0.001	0.005	0.004	0.04
Pancreas	<0.001	0.006	0.004	0.05
Red Marrow	0.01	0.04	0.1	0.3
Spleen	<0.001	0.006	0.004	0.04
Testes	0.003	0.003	0.03	0.02
Thymus	<0.001	0.007	0.004	0.06
Thyroid	<0.001	0.2	0.004	2
Urinary Bladder Wall	<0.001	0.006	0.004	0.04

* NPE = no potential for exposure.

† Organ doses were obtained from Mason (2009) and then adjusted to EPG assumptions.

The upper-bound doses in Table 4 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 5. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. Cancer Cases not Recommended for Expedited Processing for Post-GREENHOUSE Enewetak Atoll

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Thyroid	Thyroid	9

6. References

Berkhouse, L., Davis, S.E., Gladeck, F.R., Hallowell, J.H., Jones, C.B., Martin, E.J., McMullan, F.W., and Osborne, M.J., 1983. *Operation GREENHOUSE: 1951, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review.* DNA 6034F, Defense Nuclear Agency, Washington, DC. June 15.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Post-IVY Enewetak Atoll

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Post-IVY Enewetak Atoll

1. Description of the Expedited Processing Group

The Post-IVY-Enewetak Atoll Expedited Processing Group (EPG) consists of approximately 599 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak, Japtan, and Parry Islands) during the period between November 18, 1952 and February 28, 1954 (Mason, 2009).

Operation IVY is described in Gladeck et al. (1982) and DTRA (2008, Appendix B-4). After the formal end of the operation, individuals remained on Enewetak Atoll to serve as the garrison for the Pacific Proving Ground. There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for Post-IVY Enewetak Atoll

To estimate EPG doses for Post-IVY Enewetak Atoll personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort."

For this EPG, Post-IVY personnel assigned to Enewetak Island who arrived on November 18, 1952 are identified as the generic highest-dose cohort. Post-IVY personnel assigned to Enewetak Island are representative of personnel on Enewetak Atoll who received the highest dose for post-IVY personnel during the interval between IVY and Operation CASTLE.

Post-IVY personnel assigned to Enewetak Island form an adequate basis of the generic highest-dose cohort scenario (Mason, 2009 and DTRA, 2008, Appendix B-4) for this EPG for two primary reasons:

- The group was assigned to Enewetak Atoll similar to most inter-operational personnel.
- The group had no involvement in unique exposure activities.

For use with the EPG, the generic highest-dose cohort scenario is augmented with additional dose components and assumptions. The basic scenario of participation and radiation exposure of the Post-IVY personnel assigned to Enewetak Island scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Post-IVY Personnel Assigned to Enewetak Island

To estimate EPG doses for all military personnel assigned to Enewetak Atoll during the Post-IVY inter-operational period, a generic high-sided exposure scenario was developed based on activities of Post-IVY personnel assigned to Enewetak Island.

Post-IVY personnel assigned to Enewetak Island had no involvement in unique exposure activities, so their only source of exposure was fallout from Operation GREENHOUSE shots and Operation IVY shots that were conducted before their assumed arrival. The IVY shots and the resulting fallout exposure rates at Enewetak Island are shown in Table 1. Based on these exposure rates, decayed to the end of the operation and then one year beyond, the Post-IVY personnel assigned to Enewetak Island who lived on Enewetak Island accrued external doses from fallout deposited on Enewetak Island while outside and while indoors. Post-IVY personnel assigned to Enewetak Island personnel also received internal doses while outdoors during the same period from inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust (DTRA, 2008, Appendix B-4).

Table 1. Operation IVY Detonations that Affected Enewetak Island

Shot	Time and Date of Detonation (1952)	Peak Exposure Rate ($R\ hr^{-1}$)	Peak Time (H+hr)
MIKE	Nov 1 at 0715	0.000041	168
KING	May 18 at 1130	0.00012	24

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Enewetak Atoll resident cohort analysis:

- The period of exposure to Enewetak Island is assumed to be from November 18, 1952 to November 30, 1953. This start date is the end of IVY. The end date corresponds to one year later. The internal doses were calculated through a date of March 1, 1954.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning, and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 $m^3\ hr^{-1}$. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz, et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate. .

Exposure pathways for the EPG scenario are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the Post-IVY Enewetak Atoll Residents

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from two shots of Operation IVY	Post-IVY Personnel assigned to Enewetak Island were exposed residual radiation due to fallout from Shots MIKE and KING.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of resuspended fallout from two fallout episodes	Post-IVY Personnel assigned to Enewetak Island were subjected to inhalation of resuspended fallout from Shots MIKE and KING.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from two fallout episodes	Post-IVY Personnel assigned to Enewetak Island incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots MIKE and KING.	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartPIV}$	Post-IVY start date [time]	18 November 1952 [0000]
$Date_{EndPIV}$	Post-IVY end date [time]	31 November 1953 [2400]
$Date_{Departed}$	Enewetak Island departure date [time]	31 November 1953 [2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Island	0.67 (= 16/24)
PF_{tent}	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
F_B	Film badge conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
λ_{postop}	Decay exponent for post-operations	1.2 (DTRA, 2008, Appendix B-4)
λ_{6mon}	Decay exponent for post-operation for times greater than H+6 months	2.2 (DTRA, 2008, Appendix B-4)
$IpeakDet_{MK}$ $TpeakDet_{MK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MIKE	0.000041 R hr^{-1} at H+168 (DTRA, 2008, Appendix B-4)
$IpeakDet_{KG}$ $TpeakDet_{KG}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot KING	0.00012 R hr^{-1} at H+ 24 (DTRA, 2008, Appendix B-4)
$Dose_{GH}$	Dose due to residual radiation from Operation GREENHOUSE	0.01 rem (Mason, 2009)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Soil thickness	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{Ing}	Fallout inhalation (film-badge equivalent) and ingestion dose conversion factors	Per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-IVY Enewetak Atoll are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the internal EPG doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Post-IVY Enewetak Atoll Residents

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	0.03		0.09	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	<0.001	<0.001	<0.001
Bone Surface	0.02	0.007	0.2	0.07
Brain	<0.001	<0.001	<0.001	<0.001
Breast	<0.001	<0.001	<0.001	<0.001
Stomach Wall	<0.001	<0.001	<0.001	<0.001
Small Intestine Wall	<0.001	<0.001	<0.001	<0.001
Upper Large Intestine Wall	<0.001	0.001	<0.001	0.004
Lower Large Intestine Wall	<0.001	0.002	<0.001	0.009
Kidney	<0.001	<0.001	0.001	<0.001
Liver	0.003	0.002	0.03	0.02
Extra-Thoracic Region	<0.001	0.001	0.002	0.02
Lung	<0.001	0.005	0.003	0.05
Muscle	<0.001	<0.001	<0.001	<0.001
Pancreas	<0.001	<0.001	<0.001	<0.001
Red Marrow	0.001	<0.001	0.006	0.004
Spleen	<0.001	<0.001	<0.001	<0.001
Testes	<0.001	<0.001	0.002	<0.001
Thymus	<0.001	<0.001	<0.001	<0.001
Thyroid	<0.001	0.002	<0.001	0.01
Urinary Bladder Wall	<0.001	<0.001	<0.001	<0.001

* NPE = no potential for exposure.

† Organ doses were obtained from Mason (2009) and then adjusted to incorporate EPG assumptions.

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Gladeck, F.R., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R.H., Pozega, R.; Rogers, W.E., Rowland, R.H., Shelton, C.F., Berkhouse, L., Davis, S., Doyle, M.K., and Jones, C.B., 1982. *Operation IVY: 1952, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review.* DNA 6036F, Defense Nuclear Agency, Washington, DC. Dec 1.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Post-CASTLE Enewetak Atoll

November 2011

<u>Important Note</u>

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Post-CASTLE Enewetak Atoll

1. Description of the Expedited Processing Group

The Post-CASTLE-Enewetak Atoll Expedited Processing Group (EPG) consists of approximately 1063 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak, Japtan, and Parry Islands) during the period between June 1, 1954 and May 5, 1956 (Mason, 2009).

Operation CASTLE is described in Martin and Rowland (1982) and DTRA (2008, Appendix B-5. After the formal end of the operation, individuals remained on Enewetak Atoll to serve as the garrison for the Pacific Proving Ground. There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for Post-CASTLE Enewetak Atoll

To estimate EPG doses for Post-CASTLE Enewetak Atoll personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort."

For this EPG, Post-CASTLE personnel assigned to Enewetak Island who arrived on June 1, 1954 are identified as the generic highest-dose cohort. Post-CASTLE personnel assigned to Enewetak Island are representative of personnel on Enewetak Atoll who received the highest dose for post-CASTLE personnel during the interval between CASTLE and Operation REDWING.

Post-CASTLE personnel assigned to Enewetak Island form an adequate basis of the generic highest-dose cohort scenario (Mason, 2009 and DTRA, 2008, Appendix B-5) for this EPG for two primary reasons:

- The group was assigned to Enewetak Atoll similar to most inter-operational personnel.
- The group had no involvement in unique exposure activites.

For use with the EPG, the generic highest-dose cohort scenario is augmented with additional dose components and assumptions. The basic scenario of participation and radiation exposure of the Post-CASTLE personnel assigned to Enewetak Island scenario is described directly below, followed by a description of the dose components and assumptions.

3. Highest-Dose Cohort Scenario: Post-CASTLE Personnel Assigned to Enewetak Island

To estimate EPG doses for all military personnel assigned to Enewetak Atoll during the Post-CASTLE inter-operational period, a generic high-sided exposure scenario was developed based on activities of Post-CASTLE personnel assigned to Enewetak Island.

Post-CASTLE personnel assigned to Enewetak Island had no involvement in unique exposure activities, so their only source of exposure was fallout from Operation CASTLE shots that were conducted before their assumed arrival. The CASTLE shots and the resulting fallout exposure rates at Enewetak Island are shown in Table 1. Based on these exposure rates, decayed to the end of the operation and then one year beyond, the Post-CASTLE personnel assigned to Enewetak Island who lived on Enewetak Island accrued external doses from fallout deposited on Enewetak Island while outside and while indoors. Post-CASTLE personnel assigned to Enewetak Island personnel also received internal doses while outdoors during the same period from inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust (DTRA, 2008, Appendix B-5).

Table 1. Operation CASTLE Detonations that Affected Enewetak Island

Shot	Date and Time of Detonation (1954)	Peak Exposure Rate (R hr^{-1})	Peak Time (H+hr)
BRAVO	Mar 1 at 0645	0.01	16
ROMEO	Mar 27 at 0630	0.009	77.5
NECTAR	May 14 at 0620	0.002	14.7

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Enewetak Atoll resident cohort analysis:

- The period of assignment to Enewetak Island is assumed to be from June 1, 1954 to May 31, 1955. This start date is the first of the month after the last CASTLE Shot. The end date corresponds to one year later. The internal doses were calculated through a date of May 5, 1956.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning, and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al. 2009). Other

combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the Post-CASTLE Enewetak Atoll Residents

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from three shots of Operation CASTLE	Post-CASTLE Personnel assigned to Enewetak Island were exposed to residual radiation due to fallout from Shots BRAVO, ROMEO, and NECTAR.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of resuspended fallout from three fallout episodes	Post-CASTLE Personnel assigned to Enewetak Island were subjected to inhalation of resuspended fallout from Shots BRAVO, ROMEO, and NECTAR.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from three fallout episodes	Post-CASTLE Personnel assigned to Enewetak Island incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots BRAVO, ROMEO, and NECTAR.	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartPCS}$	Post-CASTLE start date [time]	1 June 1954 [0000]
$Date_{EndPCS}$	Post-CASTLE end date [time]	31 May 1955 [2400]
$Date_{Departed}$	Enewetak Island departure date [time]	31 May 1955 [2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Island	0.67 (= 16/24)
PF_{tent}	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
F_B	Film-Badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
$IpeakDet_{BR}$ $TpeakDet_{BR}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot BRAVO	0.01 R hr^{-1} at H+16 (DTRA, 2008, Appendix B-5)
$IpeakDet_{RM}$ $TpeakDet_{RM}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ROMEO	0.009 R hr^{-1} at H+ 77.5 (DTRA, 2008, Appendix B-5)
$IpeakDet_{NC}$ $TpeakDet_{NC}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot NECTAR	0.002 R hr^{-1} at H+ 14.7 (DTRA, 2008, Appendix B-5)
λ_3	Decay exponent for times between H+10 and H+48	0.82 (DTRA, 2008, Appendix B-5)
λ_4	Decay exponent for times between H+48 and H+480	1.5 (DTRA, 2008, Appendix B-5)
λ_5	Decay exponent for times between H+480 and H+4380	1.2 (DTRA, 2008, Appendix B-5)
λ_{6mon}	Decay exponent for times greater than H+6 months	2.2 (DTRA, 2008, Appendix B-5)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{Ing}	Fallout inhalation (film-badge equivalent) and ingestion dose conversion factors	Per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-CASTLE Enewetak Atoll are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the internal EPG doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Post-CASTLE Enewetak Atoll Residents

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	0.3		0.8	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.001	0.001	0.006	0.008
Bone Surface	0.3	0.2	3	2
Brain	0.001	0.001	0.006	0.005
Breast	0.001	0.001	0.006	0.008
Stomach Wall	0.001	0.002	0.006	0.008
Small Intestine Wall	0.001	0.003	0.006	0.02
Upper Large Intestine Wall	0.001	0.009	0.006	0.04
Lower Large Intestine Wall	0.001	0.03	0.006	0.1
Kidney	0.002	0.001	0.02	0.008
Liver	0.07	0.04	0.7	0.4
Extra-Thoracic Region	0.003	0.01	0.03	0.2
Lung	0.007	0.08	0.07	0.8
Muscle	0.001	0.001	0.006	0.006
Pancreas	0.004	0.003	0.04	0.03
Red Marrow	0.001	0.001	0.006	0.007
Spleen	0.02	0.009	0.2	0.08
Testes	0.001	0.001	0.006	0.005
Thymus	0.001	0.001	0.006	0.007
Thyroid	0.005	0.003	0.05	0.03
Urinary Bladder Wall	0.001	0.001	0.006	0.009

* NPE = no potential for exposure.

† Organ doses were obtained from Mason (2009) and adjusted to incorporate EPG assumptions.

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Martin, E.J. and Rowland, R.H. 1982. *CASTLE Series, 1954, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review.* DNA 6035F, Defense Nuclear Agency, Washington, DC. April 1.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Post-REDWING Enewetak Atoll

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: Post-REDWING Enewetak Atoll

1. Description of the Expedited Processing Group

The Post-REDWING-Enewetak Atoll Expedited Processing Group (EPG) consists of approximately 4.466 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak, Japtan, and Parry Islands) during the period between August 6, 1956 and May 11, 1958 (Mason, 2009).

Operation REDWING is described in Bruce-Henderson et al (1982) and DTRA (2008, Appendix B-7). After the formal end of the operation, individuals remained on Enewetak Atoll to serve as the garrison for the Pacific Proving Ground. There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for Post-REDWING Enewetak Atoll

To estimate EPG doses for Post-REDWING Enewetak Atoll personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort."

For this EPG, Post-REDWING personnel assigned to Enewetak Island who arrived on August 6, 1956 are identified as the generic highest-dose cohort. Post-REDWING personnel assigned to Enewetak Island are representative of personnel on Enewetak Atoll who received the highest dose for post-REDWING personnel during the interval between REDWING and Operation HARDTACK I.

Post-REDWING personnel assigned to Enewetak Island form an adequate basis of the generic highest-dose cohort scenario (Mason, 2009; DTRA, 2008, Appendix B-7) for this EPG for two primary reasons:

- The group was assigned to Enewetak Atoll similar to most inter-operational personnel.
- The group had no involvement in unique exposure activities.

As explained below, several dose components and assumptions were added to the documented Enewetak Island resident scenario to produce EPG doses. The Post-REDWING personnel assigned to Enewetak Island scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Post-REDWING Personnel Assigned to Enewetak Island

To estimate EPG doses for all military personnel assigned to Enewetak Atoll during the Post-REDWING inter-operational period, a generic high-sided exposure scenario was developed based on activities of Post-REDWING personnel assigned to Enewetak Island.

Post-REDWING personnel assigned to Enewetak Island had no involvement in unique exposure activities, so their only source of exposure was fallout from Operation Enewetak shots that were conducted before their assumed arrival. The REDWING shots and the resulting fallout exposure rates at Enewetak Island are shown in Table 1. Based on these exposure rates, decayed to the end of the operation and then one year beyond, the Post-REDWING personnel assigned to Enewetak Island who lived on Enewetak Island personnel accrued external doses from fallout deposited on Enewetak Island while outside and while indoors. Post-REDWING personnel assigned to Enewetak Island personnel also received internal doses while outdoors during the same period from inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust (DTRA, 2008, Appendix B-7).

Table 1. Operation REDWING Detonations that Affected Enewetak Island

Shot	Time and Date of Detonation	Peak Exposure Rates ($R\ hr^{-1}$)	Peak Time (H+hr)
ZUNI	May 28, 1956 at 0556	0.00025	11
MOHAWK	July 3, 1956 at 0606	0.01194	2.9
APACHE	July 9, 1956 at 0606	0.00084	20.9
TEWA	July 21, 1956 at 0546	0.1155	26

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Enewetak Island resident cohort analysis:

- The period of exposure to Enewetak Island is assumed to be from August 6, 1956 to August 31, 1957. This start date is the end of REDWING. The end date corresponds to the end of the month one year later. The internal doses were calculated through a date of May 12, 1958.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning, and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.
- The breathing rate for outdoor activities is increased from the default value of 1.2 to 2.0 $m^3\ hr^{-1}$. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the Post-REDWING Enewetak Atoll Residents

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from four shots of Operation REDWING	Post-REDWING Personnel assigned to Enewetak Island were exposed residual radiation due to fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of resuspended fallout from four fallout episodes	Post-REDWING Personnel assigned to Enewetak Island were subjected to inhalation of resuspended fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust from four fallout episodes	Post-REDWING Personnel assigned to Enewetak Island incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots ZUNI, MOHAWK, APACHE, and TEWA.	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartPRW}$	Post-REDWING start date[time]	6 August, 1956[0000]
$Date_{EndPRW}$	Post-REDWING end date[time]	31 August 1957 [2400]
$Date_{Departed}$	Enewetak Island departure date[time]	31 August 1957 [2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Enewetak Island	0.67 (= 16/24)
PF_{tent}	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
$IpeakDet_{ZN}$ $TpeakDet_{ZN}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot ZUNI	0.00025 R hr^{-1} at H+11 (DTRA, 2008, Appendix B-7)
$IpeakDet_{MH}$ $TpeakDet_{MH}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot MOHAWK	0.01194 R hr^{-1} at H+ 2.9 (DTRA, 2008, Appendix B-7)
$IpeakDet_{AP}$ $TpeakDet_{AP}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot APACHE	0.00084 R hr^{-1} at H+ 20.9 (DTRA, 2008, Appendix B-7)
$IpeakDet_{TW}$ $TpeakDet_{TW}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot TEWA	0.1155 R hr^{-1} at H+ 26 (DTRA, 2008, Appendix B-7)
λ_{postop}	Decay exponent for times less than H+6 months	1.2 (DTRA, 2008, Appendix B-7)
λ_{6mon}	Decay exponent for times greater than H+6 months	2.2 (DTRA, 2008, Appendix B-7)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{Ing}	Fallout inhalation (film-badge equivalent) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-REDWING Enewetak Atoll are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculation of upper-bound external doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

The upper-bound doses in Table 5 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ dose (combined external and internal doses) that is close to or exceeds the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 4. External and Internal Doses and Upper Bounds for Post-REDWING Enewetak Atoll Residents

External Doses	EPG Dose (rem)		EPG Dose (rem)	
Residual Gamma Radiation	2		6	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.006	0.02	0.05
Bone Surface	0.8	0.3	8	3
Brain	0.002	0.003	0.02	0.02
Breast	0.002	0.006	0.02	0.05
Stomach Wall	0.002	0.009	0.02	0.06
Small Intestine Wall	0.002	0.02	0.02	0.09
Upper Large Intestine Wall	0.002	0.07	0.02	0.4
Lower Large Intestine Wall	0.002	0.2	0.02	1
Kidney	0.004	0.005	0.04	0.04
Liver	0.2	0.05	2	0.5
Extra-Thoracic Region	0.008	0.2	0.08	2
Lung	0.02	0.6	0.2	7
Muscle	0.002	0.004	0.02	0.03
Pancreas	0.002	0.005	0.02	0.04
Red Marrow	0.04	0.03	0.4	0.3
Spleen	0.002	0.005	0.02	0.04
Testes	0.01	0.005	0.2	0.04
Thymus	0.002	0.006	0.02	0.06
Thyroid	0.002	0.1	0.02	0.8
Urinary Bladder Wall	0.002	0.005	0.02	0.03

* NPE = no potential for exposure.
† Organ doses were obtained from Mason (2009) and adjusted to incorporate EPG assumptions.

Table 5. Cancer Cases not Recommended for Expedited Processing for Post-REDWING Enewetak Atoll

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose below but close to the screening dose		
Thyroid	Thyroid	7

6. References

Bruce-Henderson, S., Gladeck, F.R., Hallowell, J.H., Martin, E.J., McMullan, F.W., Miller, R. H., Rogers, W.E., Rowland, C.F., Shelton, C.F, Sturman, P., Berkhouse, L., Davis, S., DeSantis, H., Dean, P., Doyle, M.K., and Patterson, D.S., 1982. *Operation REDWING: 1956, United States Atmospheric Nuclear Weapons Tests, Nuclear Test Personnel Review.* DNA 6037F, Defense Nuclear Agency, Washington, DC. August 1.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02. Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Post-HARDTACK I Enewetak Atoll

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

Expedited Processing Group: Post-HARDTACK I Enewetak Atoll

1. Description of the Expedited Processing Group

The Post-HARDTACK I-Enewetak Atoll Expedited Processing Group (EPG) consists of approximately 973 personnel that were stationed and billeted on the residence islands of Enewetak Atoll (Enewetak and Parry Islands) during the period between August 19, 1958 and April 24, 1962 (Mason, 2009 and DTRA, 2008, Appendix B-8).

Operation HARDTACK I is described in Gladeck et al. (1982) and DTRA (2008, Appendix B-8. After the formal end of the operation, individuals remained on Enewetak Atoll to serve as the garrison for the Pacific Proving Ground.

The following individuals are excluded from expedited processing under this EPG:

- Individuals who resided on Japtan Island during the Post-HARDTACK I period.

2. Basis of Dose Analysis for Post-HARDTACK I Enewetak Atoll

To estimate EPG doses for Post-HARDTACK I Enewetak Atoll personnel, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the "highest-dose cohort."

For this EPG, Post-HARDTACK I personnel assigned to Parry Island who arrived on July 6, 1958 are identified as the generic highest-dose cohort. Post-HARDTACK I personnel assigned to Parry Island are representative of personnel on Enewetak Atoll who received the highest dose for post-HARDTACK I personnel during the interval between HARDTACK I and Operation DOMINIC I.

Post-HARDTACK I personnel assigned to Parry Island form an adequate basis of the generic highest-dose cohort scenario (Mason, 2009 and DTRA, 2008, Appendix B-8) for this EPG for two primary reasons:

- The group was assigned to Enewetak Atoll similar to most inter-operational personnel.
- The group had no involvement in unique exposure activites.

For use with the EPG, the generic highest-dose cohort scenario is augmented with additional dose components and assumptions. The basic scenario of participation and radiation exposure of the Post-HARDTACK I personnel assigned to Parry Island scenario is described directly below, followed by a description of the additional dose components and assumptions.

3. Highest-Dose Cohort Scenario: Post-HARDTACK I Personnel Assigned to Parry Island

To estimate EPG doses for all military personnel assigned to Enewetak Atoll during the Post-HARDTACK I inter-operational period, a generic high-sided exposure scenario was developed based on activities of Post-HARDTACK I personnel assigned to Parry Island.

Post-HARDTACK I personnel assigned to Parry Island had no involvement in unique exposure activities, so their only significant source of exposure was fallout from Operation HARDTACK I shots that were conducted before their assumed arrival. The HARDTACK I shots and the resulting fallout exposure rates at Parry Island are shown in Table 1. Based on these exposure rates, decayed to the end of the operation and then one year beyond, the Post-HARDTACK I personnel assigned to Parry Island who lived on Parry Island accrued external doses from fallout deposited on Parry Island while outside and while indoors. Post-HARDTACK I personnel assigned to Parry Island also received internal doses while outdoors during the same period from inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust (DTRA, 2008, Appendix B-8).

Table 1. Operation HARDTACK I Detonations that Affected Parry Island

Shot	Time and Date of Detonation	Peak Exposure Rate (R hr^{-1})	Peak Time (H+hr)
FIR/KOA	May 12, 1958 at 0550	0.025*	58*
REDWOOD	June 28, 1958 at 0530	0.0003	13.5
OAK	June 29, 1958 at 0730	0.002	14
POPLAR	July 13, 1958 at 0345	0.0015	12.25
PISONIA	July 18, 1958 at 1449	0.034	3.82

* Assumed peak exposure rate and peak time for combined fallout from Shots FIR and KOA

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to the high-sided Parry Island resident cohort analysis:

- The period of exposure to Parry Island is assumed to be from July 6, 1958 to August 18, 1959. This start date is the end of HARDTACK I. The end date corresponds to the end of the month one year later. The internal doses were calculated through a date of April 25, 1962.
- The number of hours spent outdoors is increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors for sleeping, cleaning, and eating.
- Although personnel spent their time indoors in either a tent or a metal building, it is assumed that 100 percent of the time indoors was in a tent for which the protection factor (protection afforded) is 1.5 compared to a building for which the protection factor is 2.

- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50% light activity and 50% moderate activity (Weitz, et al. 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure pathways for the Post-HARDTACK I Enewetak Atoll Residents

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation due to fallout from shots of Operation HARDTACK I.	Post-HARDTACK I Personnel assigned to Parry Island were exposed residual radiation due to fallout from Shots FIR/KOA, REDWOOD, OAK, POPLAR, and PISONIA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Building protection factor is 1.5 instead of 2.
INTERNAL		
Inhalation of resuspended fallout from HARDTACK I shots.	Post-HARDTACK I Personnel assigned to Parry Island were subjected to inhalation of resuspended fallout from Shots FIR/KOA, REDWOOD, OAK, POPLAR, and PISONIA.	Time outdoors is 16 hr day^{-1} instead of 14.4 hr day^{-1}. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Incidental ingestion of contaminated soil/dust due to residual radiation from HARDTACK I shots	Post-HARDTACK I Personnel assigned to Parry Island incurred doses from incidental ingestion of soil and dust contaminated with fallout from Shots FIR/KOA, REDWOOD, OAK, POPLAR, and PISONIA.	

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{StartPHTI}$	Post-HARDTACK I start date[time]	7 July, 1958[0000]
$Date_{EndHTI}$	Post-HARDTACK I end date[time]	31 July 1959 [2400]
$Date_{Departed}$	Parry Island departure date[time]	31 July 1959 [2400]
EXTERNAL DOSE		
F_{os}	Fraction of time spent outside on Parry Island	0.67 (= 16/24)
PF_{tent}	Protection factor while indoors, assumed inside a tent	1.5 (DTRA, 2010, SM ED02)
F_B	Film-badge conversion Factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
$IpeakDet_{FK}$ $TpeakDet_{FK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot FIR/KOA	0.025 R hr^{-1} at H+58 (DTRA, 2008, Appendix B-8)
$IpeakDet_{FK}$ $TpeakDet_{FK}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot REDWOOD	0.0007 R hr^{-1} at H+ 13.5 (DTRA, 2008, Appendix B-8)
$IpeakDet_{AP}$ $TpeakDet_{AP}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot OAK	0.0025 R hr^{-1} at H+ 14 (DTRA, 2008, Appendix B-8)
$IpeakDet_{PO}$ $TpeakDet_{PO}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot POPLAR	0.0015 R hr^{-1} at H+ 12.25 (DTRA, 2008, Appendix B-8)
$IpeakDet_{PI}$ $TpeakDet_{PI}$	Peak exposure rate and time of peak exposure rate due to fallout from Shot PISONIA	0.034 R hr^{-1} at H+ 3.82 (DTRA, 2008, Appendix B-8)
λ_{postop}	Decay exponent for the first six months after detonation	1.2 (DTRA, 2008, Appendix B-8)
λ_{6mon}	Decay exponent for more than six months after detonation	2.2 (DTRA, 2008, Appendix B-8)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ (DTRA, 2010, SM ID01)
F_{os}	Fraction of time spent outside	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
$Thick$	Thickness of soil that can be resuspended	0.01 m (DTRA, 2010, SM ID01)
DCF_{inhFBE} DCF_{Ing}	Fallout inhalation (film-badge equivalent) and ingestion dose conversion factors	per FIIDOS (select maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)

5. Summary of EPG Doses and Upper-Bounds

The EPG external and internal doses and corresponding upper-bound doses for the Post-HARDTACK I Enewetak Atoll are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for calculations of upper-bound doses for expedited processing, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper-bound doses by multiplying the total dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 1 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for Post-HARDTACK I Enewetak Atoll Residents

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	0.4		1	
Initial Gamma*	NPE		NPE	
Neutron*	NPE		NPE	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.001	0.001	0.006	0.009
Bone Surface	0.4	0.05	4	0.5
Brain	0.001	<0.001	0.006	0.004
Breast	0.001	0.0001	0.006	0.007
Stomach Wall	0.001	0.002	0.006	0.02
Small Intestine Wall	0.001	0.004	0.006	0.02
Upper Large Intestine Wall	0.001	0.02	0.006	0.2
Lower Large Intestine Wall	0.001	0.06	0.006	0.4
Kidney	0.002	0.007	0.02	0.06
Liver	0.07	0.01	0.7	0.1
Extra-Thoracic Region	0.004	0.03	0.04	0.4
Lung	0.008	0.1	0.08	1
Muscle	0.007	0.001	0.006	0.005
Pancreas	0.001	0.001	0.006	0.007
Red Marrow	0.002	0.006	0.02	0.05
Spleen	0.001	0.006	0.006	0.05
Testes	0.005	0.001	0.05	0.007
Thymus	0.001	0.001	0.006	0.008
Thyroid	0.001	0.003	0.006	0.02
Urinary Bladder Wall	0.001	0.002	0.006	0.02

* NPE = no potential for exposure.

† Organ doses were obtained from Mason (2009) and adjusted to incorporate EPG assumptions.

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Gladeck, F. R., Gould, K. G., Hallowell, J. H., Martin, E. J., McMullan, F. W., Miller, R.A.,Osborn, M. J., Shelton, C. F., Berkhouse, L., and Calhoun, F. S., 1982. *Operation HARDTACK I: 1958*. DNA 6038F, Defense Nuclear Agency, Washington, DC. December 1.

Mason, C., 2009. *Doses Accrued at the Residence Islands of Enewetak Atoll from Previous Operations.* NTPR-TM-09-02, Defense Threat Reduction Agency, Fort Belvoir, VA. December 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide (Revision 4)*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R.L., 2010. *Formulation of the Gamma Source Modification Factor for Ship-based Applications (Revision 1).* NTPR-TM-09-04 (R1), Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Proposed NTPR
Expedited Processing Groups

CONUS Series

November 2011

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

NTS Observer and Maneuver Troops (1951–1962)

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: NTS Observer and Maneuver Troops (1951–1962)

1. Description of the Expedited Processing Group

The Nevada Test Site (NTS) Observer and Maneuver Troop Expedited Processing Group (EPG) consists of Army, Navy, Marine Corps and Air Force personnel who participated in an observer or maneuver program during any one of the eight NTS test series from 1951 through 1962. This EPG primarily consists of observer and maneuver troops who participated in Exercise Desert Rock (EDR) programs starting with EDR I in 1951 through EDR VII in 1958. These personnel were short-term assignees to Camp Desert Rock (CDR) who participated in formal EDR troop observer or tactical troop maneuver programs. Also included are some CDR support personnel who were participants in Exercise IVY FLATS in 1962. Although not all EPG members were stationed at CDR for the same period of time (see below), activities that may have resulted in exposure to residual radiation and the sources of residual radiation resulting in exposure of these troops were similar. Therefore, it is reasonable to include participants from all NTS test series into a single EPG.

During the eight relevant test series that were conducted at the NTS from 1951 to 1962, approximately 42,600 members of the Army, Navy, Marine Corps and Air Force participated as official observers and in tactical troop maneuvers (Table 1). Observer and maneuver troops were typically billeted at CDR. Most of these troops traveled from their home station to CDR specifically to participate in observer or maneuver activities. These troops spent only a short time at CDR (e.g., 1–2 weeks), and their participation consisted solely as observer or maneuver troops. Other observer and maneuver troops were composed of CDR support troops, i.e., those troops who provided support functions for the camp or conducted EDR activities. These troops were drawn from units of the Sixth Army, and were generally stationed at the camp throughout the series, although many did not remain for the entire period. Only those CDR support troops whose CDR support assignment did not require them to routinely enter the forward test area are included in this EPG (e.g., administration, mess services, band, and laundry services personnel) (e.g., Ponton et al., 1982a).

As described above, this EPG generally consists of military personnel who participated only as an observer or maneuver troop during any one of the eight NTS test series. However, doses in this EPG should not be assigned to any observer or maneuver participant for whom any of the general exclusions for NTS personnel are applicable. This includes CDR support troops who are known to have participated in or supported maneuvers and may have also been required to enter the forward test area to help prepare for later EDR activities, assist in operations during a test event, or help with recovery operations after other shots. In addition to the general exclusions, the following individuals, units, cohorts, or individuals are excluded from expedited processing under this EPG:

- Individuals who participated in one of the Volunteer Observer Programs conducted during some of the test series. Volunteer observers—typically officers—were positioned in trenches well forward of other observers, and they did not always participate in all observer activities.
- Any individuals who participated in more than one maneuver group at more than one shot.

- Individuals who were members of the 2nd Marine Corps Provisional Atomic Exercise Brigade at UPSHOT-KNOTHOLE Shot BADGER or Task Force WARRIOR at PLUMBBOB Shot SMOKY (EDR VII/VIII Project 50.1). These groups are each evaluated in a different EPG.

Two Appendices describe dose analyses for specific groups that are included in this EPG, even though their activities might otherwise cause them to be excluded. Appendix A describes a dose analysis for CDR support troops who were members of the 505th Military Police Battalion that participated during Operations UPSHOT-KNOTHOLE or TEAPOT. Members of the 505th Military Police Battalion would normally be excluded from any EPGs based on the general exclusion relating to routine forward area activities. Appendix B describes a dose analysis for a maneuver group (Task Force BIG BANG) that participated during Operation PLUMBBOB. This group was originally a distinct EPG, but as described in Appendix B they may be included in this EPG. Based on the magnitude of the calculated doses listed in these two, Appendices, personnel in both of these units may be included in the NTS Observer and Maneuver Troop EPG, provided that no other general exclusions apply.

Table 1. Approximate Number of Army, Navy, Marine Corps and Air Force Observer and Maneuver Troop Participants in NTS Test Series

NTS Test Series (year)	Program(s)	Observer Troops	Maneuver Troops	Totals
RANGER (1951)*	-	3	0	3
BUSTER-JANGLE (1951)	EDR I, II, III Troop Observer, and Troop Maneuver	3,127	1,095	4,222
TUMBLER-SNAPPER (1952)	EDR IV Troop Observer, and Tactical Troop Maneuvers	2,850	4,875	7,725
UPSHOT-KNOTHOLE (1953)	EDR V Troop Orientation and Indoctrination, and Tactical Troop Maneuvers	4,480	11,125	15,605
TEAPOT (1955)	EDR VI Service and Troop Observers (Projects 41.3, 41.4, 40.11, 41.7, 41.8), and Troop Tests (Projects 41.2, 41.6)	4,600	3,271	7,871
PLUMBBOB (1957)	EDR VII, VIII Troop Observers (Projects 50.2 and 52,2), and Troop Maneuvers (Projects 50.1, 52.1 and Task Force BIG BANG)	4,631	1,517	6,148
HARDTACK-II (1958)†	-	0	0	0
DOMINIC-II (1962)	Exercise IVY FLATS	500	549	1,049
Totals		20,191	22,432	42,623

* During RANGER, a brigadier general assigned to the Atomic Energy Commission, a Marine officer assigned to Los Alamos Scientific Laboratory, and a Navy officer assigned to the U.S. Public Health Service may have observed one or more shots from south of the Control Point (Maag et al., 1982).

† There were no military observer or maneuver troops at HARDTACK-II; listed here only for completeness (Ponton et al., 1982b).

2. Basis of Dose Analysis for NTS Observer and Maneuver Troop EPG

An exposure scenario was developed based on activities of the cohort group that received the highest external dose and associated internal doses from residual radiation. This cohort is referred to as the “highest-dose cohort”. Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a “highest-dose cohort” because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the activities of Battalion Combat Team Able (BCT-A) at Shot SIMON during Operation UPSHOT-KNOTHOLE form the basis for the generic highest-dose cohort scenario (Part IV of DTRA, 2008). The SIMON BCT-A scenario forms an adequate basis for the generic highest-dose cohort scenario for this EPG for two primary reasons:

- This group received the largest external gamma dose from residual radiation for all NTS observer and maneuver troops.
- The activities of this group are well-documented and are representative of other NTS observer and maneuver troops.

As explained below, several dose components and assumptions were added to the documented SIMON BCT-A scenario (Edwards et al., 1985) to produce maximized doses. The basic SIMON BCT A scenario is described directly below, followed by a description of the additional maximizing assumptions.

3. Highest-Dose Cohort Scenario: SIMON BCT-A Scenario

Approximately 2,450 Army and Air Force troops participated in the maneuver at Shot SIMON. These troops were roughly divided into halves to form two BCTs. The maneuver troops arrived at CDR by April 22, 1953, with some troops arriving as early as April 19. On April 22, an orientation at CDR was provided for BCT-A, and a rehearsal of the shot-day activities was conducted in the forward test area on April 23. At shot time (0430 on April 25) all maneuver troops were in trenches 4,000 yards from ground zero (GZ). Fourteen minutes after the blast, both BCTs began their simulated attack to their objectives. The advance continued until the BCT-A radiological monitors ordered a halt. The troops then began moving northwest to avoid high radiation exposure rates. The forward advance was again halted at 0600 hours at a location about 1,400 yards from GZ. BCT-A then turned around and moved to the 2000-yard line of the equipment display area for an examination of the equipment there. The BCT troops then moved back to the trench area, examining the display equipment along the way. At the trench area, the troops mustered and then boarded vehicles for the return to CDR, departing at about 0800-0815 hours. The point values of exposure rates estimated from contour plots and the modeled exposure rate function encountered by the BCT-A troops during the maneuver and display area tour are depicted in Figure 1 (DTRA, 2008; Edwards et al., 1985).

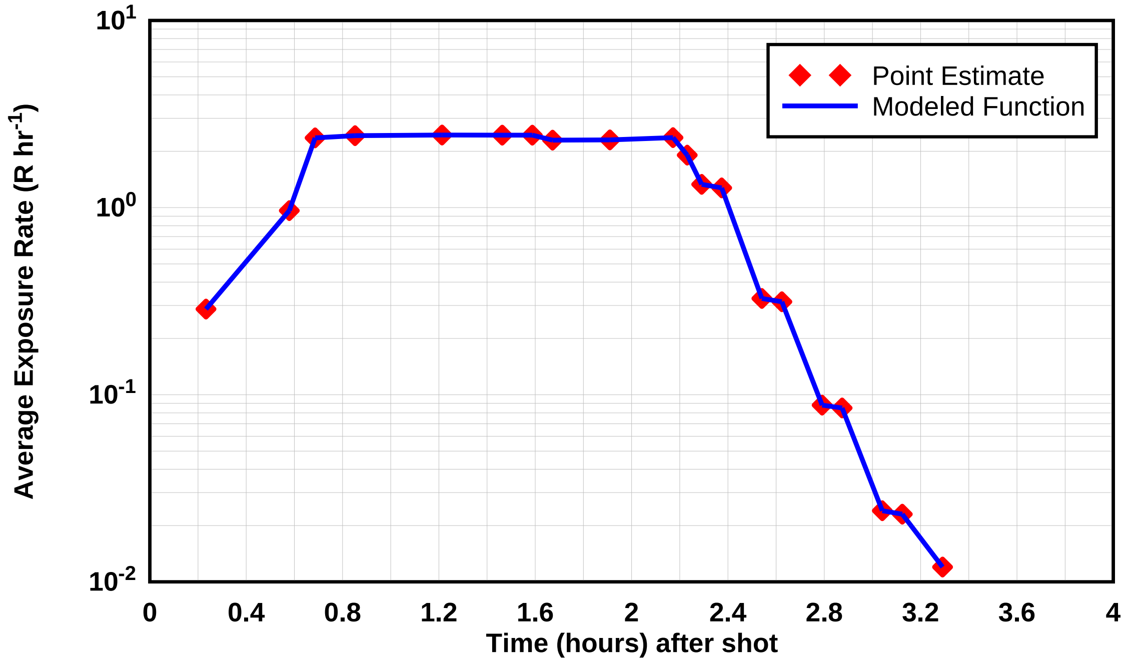

Figure 1. Residual Exposure Rates Encountered by SIMON BCT-A Maneuver Troops during Maneuver and Display Area Tour

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to or substituted into the highest-dose cohort analysis (SIMON BCT-A scenario) are described below.

Members of SIMON BCT-A were at CDR for approximately eight days, and the typical period of assignment to CDR was less than one month. However, some CDR support troops in this EPG may have been stationed at CDR for extended periods of time. Therefore, a 3-month period of assignment at CDR was used for the EPG analysis. This corresponds to the 3-month period starting on the day of fallout at CDR and ending one month after the end of the operation. This maximizes the exposure to fallout deposited at CDR (DTRA, 2008; VA, 2010).

Members of SIMON BCT-A were exposed to fallout at CDR. Fallout from four NTS shots is known to have been deposited at CDR:

- Shot CHARLIE, Operation TUMBLER-SNAPPER (1952).
- Shot BADGER, Operation UPSHOT-KNOTHOLE (1953).
- Shot POST, Operation TEAPOT (1955).
- Shot WILSON, Operation PLUMBBOB (1957).

In order to maximize both external and internal doses from fallout at CDR, it is assumed that a member of this EPG was exposed to Shot POST fallout, which resulted in the largest total organ doses of any of the fallout events. (DTRA, 2008). External and internal doses from Shot POST fallout were calculated for this EPG.

Members of SIMON BCT-A were not exposed to descending fallout. However, some members of the EPG were at CDR during periods of descending fallout there. Therefore, exposure to descending POST fallout at CDR was included as a maximizing dose pathway for all members of the EPG.

The number of hours spent outdoors at CDR by observer and maneuver troops was increased from the CDR default of 14.4 to 16 hr day^{-1}, while 8 hours each day were spent in a tent while sleeping, cleaning and eating. This affects the internal and external doses from fallout at CDR.

The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 $m^3\ hr^{-1}$. The higher value is based on the assumption of personnel activities consisting of a mix of 50 percent light activity and 50 percent moderate activity Weitz et al. (2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Some members of the EPG were subject to inhalation doses from blast-driven resuspension of previously-deposited fallout. Such doses are included in the EPG analysis and are based on the highest organ doses from blast effects for any NTS observer or maneuver group. Scenarios for which previously-calculated doses exist for observer and maneuver troops that were exposed to blast-driven resuspension include the participation at the following shots (DTRA, 2008):

- Shot FOX, Operation TUMBLER-SNAPPER (1952).
- Shots ANNIE, NANCY, HARRY and BADGER, Operation UPSHOT-KNOTHOLE (1953).
- Shots TESLA, BEE, APPLE I and APPLE II, Operation TEAPOT (1955).
- Shot BOLTZMANN, Operation PLUMBBOB (1957).

In order to maximize internal doses, it is assumed that all members of this EPG were exposed to blast-driven resuspended fallout corresponding to the observers at Operation UPSHOT-KNOTHOLE Shot HARRY. Doses for these exposures were calculated using the current recommended effective resuspension factors for blast effects, and were adjusted to account for a breathing rate higher than the default value (DTRA, 2008; Kocher et al., 2009).

Exposure pathways for the maximized scenario are described in Table 2. The values used for the primary parameters in the maximized external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for the NTS Observer and Maneuver Troop

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation during maneuver and display area tour	SIMON BCT-A troops were exposed to the SIMON fallout radiation field between about H+0.23 and H+3.3	
Residual radiation from fallout at billet location	EPG members were exposed to POST fallout at CDR from their arrival date until departure.	Assignment at CDR is approximately 91 days instead of 8 days. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
INTERNAL		
Inhalation of descending fallout at CDR	Members of the EPG were exposed to descending POST fallout at CDR.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during maneuver and display area tour	SIMON BCT-A troops inhaled resuspended fallout during the entire period of their maneuver and display area tour.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of blast-driven resuspended fallout, deposited by earlier shots, during display area tour	Members of the EPG were exposed to blast-driven resuspended fallout, as estimated for observers at Shot HARRY.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout at CDR	SIMON BCT-A troops inhaled resuspended fallout while outdoors at CDR from their arrival date until their departure.	Inhalation of resuspended fallout at CDR for approximately 91 days instead of 8 days. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
Incidental ingestion of contaminated soil/dust at CDR	SIMON BCT-A troops incurred doses from incidental ingestion of soil and dust contaminated with fallout at CDR, from their arrival date until departure.	Incidental ingestion of fallout at CDR for approximately 91 days instead of 8 days.

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$	CDR start date[time] (day of fallout at CDR)	9 Apr 55[1348]
$Date_{Departed}$	CDR end date[time] (1 month after end of operation)	10 Jul 55[1200]
EXTERNAL DOSE		
ST	Departure time from trenches to start maneuver	H+0.23 (14 min)
-	Departure time from trench area after maneuver and display area tour	H+3.3
Ratewalk	Walk rates during maneuver and display area tour	30–70 yd min^{-1}
LT1	Linger time at 450-yard line	5 min
LT2 - LT5	Linger time at each display (at 2,000, 2,500, 3,000, and 3,500 yards)	5 min
Int(t)	Residual exposure rates encountered by maneuver troops during maneuver and display area tour	see Figure 1
Int_{CDR}	Peak POST exposure rate at CDR	0.0014 R hr^{-1} (DTRA, 2008, Appendix C-6)
Tpkint	Time of peak POST exposure rate at CDR	H+12.8 (DTRA, 2008, Appendix C-6)
-	Duration of exposure to POST fallout at CDR	2216 hr
F_{os}	Fraction of time spent outside at CDR	0.67 (= 16/24)
F_{tent}	Fraction of indoor time at CDR spent in a tent	1.0
PF_t	Protection factor while indoors at CDR (tent)	1.5
TWSF	Time-Weighted Shielding Factor for time at CDR (calculated using F_{os}, F_{tent}, and PF_t)	0.889
λ	Default fallout exposure rate decay exponent for times less than 6 months after shot (used as $[H+hours]^{\lambda}$)	−1.2
F_B	Film badge equivalent conversion factor	0.7 rem R^{-1} (DTRA, 2010)
UF_{ext}	Upper bound factor for external doses	3 (DTRA, 2010, SM UA01)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (DTRA, 2010, SM UA01)
K_{pc}, K_{bw}	Resuspension factors for fallout in precursor (thermal pulse) or blast wave regions due to detonation effects	$K_{pc} = 1\times10^{-3}$ m^{-1} $K_{bw} = 1\times10^{-4}$ m^{-1} (DTRA, 2010, SM UA01)
F_{os}	Fraction of time spent outside at CDR	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM UA01)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM UA01)
DCF_{Inh} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (selected maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM UA01)
UF_{int}	Upper bound factor for internal doses	10 (DTRA, 2010, SM UA01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for NTS Observer and Maneuver Troops are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for expedited processing doses, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound external doses by multiplying the total external dose by an uncertainty factor of 3. The upper bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust, and from inhalation of blast-driven resuspended fallout, which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

The upper-bound doses in Table 4 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. However, the upper-bound EPG doses do not include contributions from initial radiation, which must be considered for cases involving certain organs before processing these cases using expedited processing. Several cohorts that are included in this EPG received neutron and initial gamma doses while participating as observers or maneuver troops. For most of the cohorts these doses are less than 1 rem (Weitz and Egbert, 2010) and have no effect on whether a total upper-bound organ dose that includes the initial doses is close to or exceeds either the corresponding screening dose or the dose corresponding to 40% probability of causation (DTRA, 2011). However, several cohorts received initial neutron or gamma upper-bound doses higher than 1 rem. Of those cohorts with high initial doses, the only cohort for whom consideration of initial doses makes a difference with regard to the comparison of total organ doses with screening doses is the observers at Shot TESLA during Operation TEAPOT (Weitz and Egbert, 2010). The upper-bound initial doses for this cohort are 4 rem from neutrons and 1 rem from initial gamma radiation.

To assess the impacts of initial doses on expedited processing decisions for members of this EPG, total upper-bound organ doses (combined upper-bounds for EPG external, EPG internal, and initial doses) were calculated for all organs. The upper-bound initial doses for TESLA observers were used in order to cover all cohorts in the EPG. The resulting total upper-bound organ doses that are close to or exceed corresponding screening doses (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 5. The total upper-bound organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40 percent (DTRA, 2011). Because of the potential for initial doses for some members of this EPG, in cases involving any of the organs listed in Table 5 the EPG upper-bound doses may not be appropriate for assignment to members of this EPG without further analysis as discussed in DTRA (2011).

Table 4. External and Internal Doses and Upper Bounds for NTS Observer and Maneuver Troops

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	4		10	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.01	0.008	0.02
Bone Surface	2	0.1	5	0.2
Brain	0.002	0.004	0.008	0.006
Breast	0.002	0.009	0.008	0.01
Stomach Wall	0.002	0.02	0.008	0.05
Small Intestine Wall	0.002	0.03	0.008	0.07
Upper Large Intestine Wall	0.002	0.2	0.008	0.2
Lower Large Intestine Wall	0.002	0.3	0.008	0.4
Kidney	0.005	0.007	0.02	0.009
Liver	0.3	0.02	1	0.03
Extra-Thoracic Region	0.02	0.4	0.05	0.7
Lung	0.03	2	0.1	2
Muscle	0.002	0.007	0.008	0.009
Pancreas	0.002	0.008	0.008	0.02
Red Marrow	0.06	0.04	0.3	0.05
Spleen	0.002	0.007	0.008	0.01
Testes	0.02	0.003	0.06	0.005
Thymus	0.002	0.01	0.008	0.02
Thyroid	0.002	0.5	0.008	0.8
Urinary Bladder Wall	0.002	0.009	0.008	0.02

* Initial gamma and neutron doses are treated separately and are based on the actual participant's exposure conditions at the time of detonations.

† Internal doses for this EPG are dominated by the dose from the inhalation of blast-driven resuspended fallout for which only upper bound values are evaluated. The contributions to EPG and upper bound EPG doses from inhalation of blast-driven resuspended fallout are numerically equal.

Table 5. Cancer Cases not Recommended for Expedited Processing for NTS Observer and Maneuver Troops

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal + Initial) (rem)
Total upper-bound dose larger than the screening dose		
Liver	Liver	16
Thyroid	Thyroid	16
Total upper-bound dose below but close to the screening dose		
Gallbladder	Liver	16
Bile Duct	Liver	16
Acute Lymphocytic Leukemia	Red Bone Marrow	16

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*. Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Edwards, R., Goetz, J., and Klemm, J., 1985. *Analysis of Radiation Exposure for Maneuver Troops, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE*. DNA-TR-84-303, Defense Nuclear Agency, Washington, DC. October 15.

Kocher, D.C., Trabalka, J.R., Apostoaei, A.I., 2009. *Derivation of Effective Resuspension Factors in Scenarios for Inhalation Exposure Involving Resuspension of Previously-Deposited Fallout by Nuclear Detonations at Nevada Test Site*. DTRA-TR-09-15, Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Maag, C., Rohrer, S., and Shepanek, R., 1982. *Operation RANGER, Shots ABLE, BAKER, EASY, BAKER-2, FOX, 25 January – 6 February 1951*. DNA 6022F, Defense Nuclear Agency, Washington, DC. February 26.

Ponton, J., Massie, J., Maag C., Shepanek, R., and Rohrer, S., 1982a. *Operation UPSHOT-KNOTHOLE, 1953*. DNA 6014F, Defense Nuclear Agency, Washington, DC. January 11.

Ponton, J., Rohrer, S., Maag, C., Shepanek, R., and Gravitis, I., 1982b. *Operation HARDTACK II, 1958*. DNA 6026F, Defense Nuclear Agency, Washington, DC. December 3.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's*

Guide Revision 4. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

VA (Department of Veterans Affairs), 2010. "Disease subject to presumptive service connection", Title 38, Part 3.309, Electronic Code of Federal Regulations. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl. Accessed October 18.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R. L., and Egbert, S. D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

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Appendix A Dose Analysis for the 505th Military Police Battalion at Operations UPSHOT-KNOTHOLE and TEAPOT

This Appendix addresses the dose evaluation for Army personnel who were assigned to the 505th Military Police Battalion (505 MPB) with temporary duty at CDR, Nevada during Operation UPSHOT-KNOTHOLE (1953) or TEAPOT (1955). Because of their routine duties in NTS forward areas, these troops would normally be excluded from any EPGs. The purpose of the analysis in this Appendix is to describe the evaluation of their doses and provide justification for including them in the NTS Observer and Maneuver Troop EPG.

A-1 Description of the Group

The group addressed here is composed of members of the 505 MPB that participated at the NTS in 1953 or 1955. This group of military police (MP) provided routine MP duties at CDR during UPSHOT-KNOTHOLE and TEAPOT. Their mission also included providing traffic control for all military vehicular movement at the NTS during EDR activities. In this capacity, the MPs were exposed to residual radiation in the NTS forward test area during rehearsals and shot-day activities for the 14 shots involving military participation in a shot area during these two operations. As CDR support personnel, these troops also participated in a maneuver, and likely also participated as observers at a detonation. Therefore, the 505 MPB activities that may have resulted in exposure to residual radiation and the sources of residual radiation resulting in exposure were similar to those of the NTS Observer and Maneuver Troop EPG, and it is reasonable to consider including them in the larger EPG provided that they do not meet any other general exclusions (DTRA, 2011; Edwards et al., 1985; Frank, 1982; Goetz et al., 1981).

A-2 Basis for 505 MPB Dose Analysis

The exposure scenarios of individual 505 MPB members while conducting their forward test area duties were similar for all members of the 505 MPB, although participation at specific shots may have differed. In order to control the vehicular movements of all participating groups, the MPs were assigned tasks in two general categories, Traffic Control (TC) and March Unit Guide (MG). TC duties involved postings at road junctions leading into and out of a shot area before and following a detonation, and MG duties involved leading march units to and from the troop trench areas. Both of these general duties are described in more detail below (Frank, 1982).

Traffic Control: Personnel of the 505 MPB assigned to this duty were posted at road junctions along the route leading into and out of the shot area. These men (one or two men at each location) were posted approximately 30 minutes prior to the arrival of the first march unit, and they remained at these posts until the last march unit had passed. They were then picked up and taken to a parking area where they remained during the detonation. Shortly after the detonation, the MPs were again posted at the road junctions along the planned route. The MPs were picked up and returned to CDR after the last convoy elements had passed.

March Unit Guides: MPs were also assigned to the march units participating in the shot activities to assist in the movement of the vehicles into and out of the shot areas. March units were established for the control group, troop maneuver units, and troop observer units. The MPs traveled in jeeps at the front of each march unit. The MPs led the march units to the troop trenches, and then led the trucks to a parking area where they remained during the detonation. When the trucks were called back to the troop loading area, the MPs again led the march units. They remained at the loading area while the troops loaded onto the trucks and then led the elements of the convoy back to CDR.

A-3 Highest-Dose Exposure Scenario

There are three 505 MPB cohorts considered: Co. C that was assigned to CDR for all of Operation UPSHOT-KNOTHOLE (1953); Co. A that was assigned to CDR from January 4–March 2, 1955 (Operation TEAPOT); and Co. C that was assigned to CDR from March 2–May 13, 1955 (Operation TEAPOT). Note that although Co. C was assigned to CDR for multiple operations, individual members of the unit may not have been present for more than one operation. To estimate bounding doses for all 505 MPB troops participating at either UPSHOT-KNOTHOLE or TEAPOT, an exposure scenario was developed based on activities of the cohort group that received the highest external dose and associated internal doses from residual radiation while participating during a single operation. The highest-dose cohort scenario is Co. C that was assigned to CDR during the entire UPSHOT-KNOTHOLE series (henceforth referred to simply as “Co. C”). In addition to routine MP duties at CDR, members of Co. C participated in rehearsals and shot-day activities for the seven UPSHOT-KNOTHOLE shots in the forward test area involving military participation (Shots ANNIE, NANCY, BADGER, SIMON, ENCORE, HARRY, and GRABLE). In the forward area, the MPs were assigned tasks in two major categories, traffic control and march unit guide as described above. As a maximizing technique, the generic Co. C MP is assumed to have participated in the activity at each shot that resulted in the largest external dose. This implies performing march guide duty at Shots ANNIE, NANCY, HARRY and GRABLE, and traffic control duty at Shots BADGER and SIMON. There was no involvement in a contaminated area for ENCORE. (Frank, 1982; Ortlieb, 1991; Philips, 1983).

Other activities involving Co. C personnel may have included participation in a maneuver as part of Battalion Combat Team-A at Shot ANNIE, and participation as part of the over 500 CDR support troops that participated in the observer program at Shot HARRY. For the purpose of evaluating the Co C. doses, it is assumed to be unlikely that a member of Co. C participated in both the ANNIE observer program and the HARRY maneuver program. Participation as a maneuver troop at ANNIE would have fulfilled the goal to have all CDR support troops observe a detonation, making it unnecessary to also participate at HARRY. Likewise, if an individual conducted MP duties at ANNIE instead of participating in the maneuver, it is more likely that they would have participated in the observer program at Shot HARRY. Because the external gamma dose for observers at HARRY is larger than the external gamma dose for maneuver troops at ANNIE, it is assumed for this analysis that Co. C participated in the observer program at Shot HARRY and conducted MP duties at Shot ANNIE. (Edwards, et al., 1985; Goetz et al., 1981).

505 MPB personnel were assigned to CDR during periods of fallout there, so exposure to descending POST fallout at CDR (during TEAPOT) is assumed for the analysis (Edwards, et al., 1985; Frank, 1982; Goetz et al., 1981).

Other assumptions similar to those used in the NTS Observer and Maneuver EPG were used for the analysis of Co. C doses, such as departure from CDR one month after the end of the operation. In particular, the exposure pathways described in Table A-1 were incorporated.

Table A-1. Exposure Pathways for Co. C, 505th Military Police

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation during MP duties in the forward test area	Co. C troops conducted MP guide duty at Shots ANNIE, NANCY, HARRY and GRABLE, and MP traffic control duty at Shots BADGER and SIMON	
Residual radiation during display area tour	Co. C troops participated as observers at UPSHOT-KNOTHOLE shot HARRY.	
Residual radiation from fallout at billet location	Co. C troops were exposed to fallout at CDR from the date of fallout until the end of the operation (approximately 63 days).	Assignment at CDR ends one month after the end of the operation, approximately 92 days after CDR fallout instead of 63 days. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
INTERNAL		
Inhalation of descending fallout at CDR	Co. C troops were exposed to descending fallout at CDR.	Breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during MP duties in the forward area.	Co. C troops were exposed to resuspended fallout while at their duty locations in the forward test areas on 7 shot days.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout during display area tour	Co. C troops inhaled resuspended contaminants during the entire period of their display area tour.	Inhalation of resuspended HARRY fallout with a breathing rate of 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of ,blast-driven resuspended fallout, deposited by earlier shots, during display area tour	Co. C troops were exposed to blast-driven resuspended fallout at Shot HARRY test area.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout at CDR	Co. C troops were subjected to inhalation of resuspended fallout at CDR from the date of fallout until the end of the operation (approximately 63 days).	Assignment at CDR ends one month after the end of the operation, approximately 92 days after CDR fallout instead of 63 days. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
Incidental ingestion of contaminated soil/dust at CDR	Co. C troops incurred doses from incidental ingestion of soil and dust contaminated with fallout at CDR, from the date of fallout until the end of the operation (approximately 63 days).	Assignment at CDR ends one month after the end of the operation, approximately 92 days after CDR fallout instead of 63 days.

A-4 Doses and Upper Bounds

The external and internal doses and corresponding upper-bound doses for Co. C, 505 MPB are summarized in Table A-2. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the total dose. However, for the expedited processing analysis, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound external doses by multiplying the total external dose by an uncertainty factor of 3. The upper bound internal doses are calculated by multiplying the total internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust, and from inhalation of blast-driven resuspended fallout, which are estimated as upper-bound doses (DTRA, 2010). The upper-bound doses in Table A-2 are not less than the upper-bound doses potentially accrued by any member of the 505 MPB that participated at UPSHOT-KNOTHOLE or TEAPOT.

A-5 Comparison of 505 MPB Doses to NTS Observer and Maneuver EPG Doses

In order to support inclusion of members of the 505 MPB that participated at Operation UPSHOT-KNOTHOLE or Operation TEAPOT in the larger NTS Observer and Maneuver Troop EPG, a comparison of the upper-bound doses has been made. The upper-bound doses for the NTS Observer and Maneuver Troop EPG are shown in Table 4, and the 505 MPB upper-bound doses are in Table A-2. Ratios of the respective upper-bound doses are shown in Table A-3. Ratios greater than 1.0 indicate that the 505 MPB dose is larger than the respective NTS Observer and Maneuver Troop EPG dose.

The dose ratios in Table A-3 show that the Co. C, 505 MPB doses are very similar to the corresponding NTS Observer and Maneuver Troop EPG doses. All corresponding external and internal doses are within a factor of 2 of each other, and most 505 MPB doses are equal to or less than corresponding NTS Observer and Maneuver EPG doses. The largest difference in doses is that for the external gamma dose, for which the 505 MPB upper-bound dose is 1 rem lower than the corresponding NTS Observer and Maneuver Troop EPG doses. Differences in upper-bound internal doses are much smaller: the largest difference is 0.1 rem for the beta+gamma dose to lower large intestine wall (ratio is 1.2). The relatively large dose ratio of 2.0 for beta+gamma doses to breast represents an actual dose difference of only 0.01 rem.

For evaluating whether the 505 MPB may be included in the NTS Observer and Maneuver Troop EPG, two points relevant to the doses are considered. These points are important to an understanding of the total organ doses, and their subsequent use in the NTPR Program.

- The 505 MPB upper-bound external dose is 1 rem lower than that of the NTS Observer and Maneuver Troop EPG.
- For internal organ doses for which the 505 MP dose is larger than the corresponding NTS Observer and Maneuver EPG dose, no 505 MP dose is more than 0.1 rem larger than the corresponding NTS Observer and Maneuver Troop EPG dose.

Table A-2. External and Internal Doses and Upper Bounds for the 505 MPB at UPSHOT-KNOTHOLE or TEAPOT

External Doses	Dose (rem)		Upper-Bound Dose (rem)	
Residual Gamma Radiation	3		9	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**Dose† (rem)**		**Upper-Bound Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.002	0.01	0.008	0.02
Bone Surface	1	0.1	5	0.2
Brain	0.002	0.004	0.008	0.006
Breast	0.002	0.009	0.008	0.02
Stomach Wall	0.002	0.02	0.008	0.05
Small Intestine Wall	0.002	0.03	0.008	0.06
Upper Large Intestine Wall	0.002	0.2	0.008	0.2
Lower Large Intestine Wall	0.002	0.3	0.008	0.5
Kidney	0.005	0.007	0.02	0.01
Liver	0.3	0.02	1	0.03
Extrathoracic Region	0.01	0.4	0.05	0.7
Lung	0.03	1	0.1	2
Muscle	0.002	0.007	0.008	0.009
Pancreas	0.002	0.008	0.008	0.02
Red Marrow	0.06	0.04	0.3	0.05
Spleen	0.002	0.008	0.008	0.01
Testes	0.02	0.003	0.07	0.005
Thymus	0.002	0.01	0.008	0.02
Thyroid	0.002	0.5	0.008	0.8
Urinary Bladder Wall	0.002	0.009	0.008	0.02

* Initial gamma and neutron doses are treated separately and are based on the actual participant's exposure conditions at the time of detonations.

† Internal doses for this cohort are dominated by the dose from the inhalation of blast-driven resuspended fallout for which only upper bound values are evaluated. The contributions to total and upper bound doses from inhalation of blast-driven resuspended fallout are numerically equal.

Subsequent use of doses assigned to a veteran in the NTPR program involves an evaluation of the likelihood that the total organ dose is the cause of the veteran's disease. Because the large difference in external doses (1 rem) far exceeds the small differences in internal doses for any organ (0.1 rem maximum), total organ doses for all organs in the NTS Observer and Maneuver EPG are much larger than those estimated for the 505 MPB. The small differences in internal organ doses, especially at the level of these doses, are insignificant with regard to the likelihood that they might be the cause of a veteran's disease. Therefore, including the 505 MPB UPSHOT-KNOTHOLE and TEAPOT troops in the larger NTS Observer and Maneuver Troop EPG will not result in any meaningful underestimates of any organ doses for any member of the 505 MPB participating at Operation UPSHOT-KNOTHOLE or Operation TEAPOT.

Table A-3. Comparison of Doses for 505 MPB and NTS Observer & Maneuver Troop EPGs

	Upper-bound Dose Ratios (505 MPB / NTS ObsMan EPG)	
External Dose Ratio	0.9	
Internal Dose Ratios for Standard NTPR Organs	**Alpha**	**Beta + Gamma**
Adrenals	1.0	1.0
Bone Surface	1.0	1.0
Brain	1.0	1.0
Breast	1.0	**2.0** (0.01)*
Stomach Wall	1.0	1.0
Small Intestine Wall	1.0	0.9
Upper Large Intestine Wall	1.0	1.0
Lower Large Intestine Wall	1.0	**1.2** (0.1)
Kidney	1.0	**1.1** (0.001)
Liver	1.0	1.0
Extra-Thoracic Region	1.0	1.0
Lung	1.0	1.0
Muscle	1.0	1.0
Pancreas	1.0	**2.0** (0.01)
Red Marrow	1.0	1.0
Spleen	1.0	1.0
Testes	**1.2** (0.01)	1.0
Thymus	1.0	1.0
Thyroid	1.0	1.0
Urinary Bladder Wall	1.0	1.0

* For dose ratios greater than 1.0, the amount (rem) that the 505 MPB dose exceeds the NTS Observer Maneuver EPG dose is shown in parentheses.

A-6 Appendix A References

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*, DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Edwards, R., Goetz, J., and Klemm, J., 1985. *Analysis of Radiation Exposure for Maneuver Troops, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE*. DNA-TR-84-303, Defense Nuclear Agency, Washington, DC. October 15.

Frank, G. 1982. "Radiation Dose for Personnel of the 505th Military Police (MP) Battalion, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE," Memorandum to File. Science Applications, Inc., McLean, VA. February 15.

Goetz, J., Kaul, D., Klemm, J., McGahan, J., and Weitz, R., 1981. *Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE.* DNA 5742F, Defense Nuclear Agency, Washington, DC. April 28.

Ortlieb, E., 1991. "Radiation Dose Reconstruction for Personnel of Companies A and C of the 505th Military Police Battalion, Exercise Desert Rock VI, Operation TEAPOT," Memorandum to M. Owais (DNA-RARP/NTPR). Science Applications International Corporation, McLean, VA. November 7.

Phillips, J., 1983. "Radiation Dose Estimate for Personnel of the 505th Military Police Battalion, Exercise Desert Rock VI, Operation TEAPOT," Memorandum to File, Science Applications, Inc., McLean, VA. December 5.

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Appendix B Dose Analysis for Task Force BIG BANG at Operation PLUMBBOB

This Appendix addresses the dose evaluation for Army personnel who were members of Task Force BIG BANG (TFBB) at the Nevada Test Site (NTS) during Operation PLUMBBOB in 1957. The purpose is to describe the evaluation of their doses and provide justification for including them in the NTS Observer and Maneuver Troop EPG.

B-1 Description of the Group

TFBB was a provisional company from the 82nd Airborne Division that participated in rehearsals and an exercise at the NTS in 1957. Most members of TFBB arrived at the NTS in mid-August, and their participation culminated with an exercise sponsored by the Human Resources Research Office (HumRRO) in conjunction with Shot GALILEO on September 2, 1957. TFBB activities included training that began upon arrival at Camp Desert Rock (CDR), rehearsals, baseline testing, and the exercise on September 2. All training was conducted at CDR. The rehearsals, baseline testing, and the HumRRO exercise were conducted in the forward NTS test area, and included observation of one or more shots from News Nob, observation of Shot GALILEO from Mercury Highway, and performance of specific military tasks prior to and following a detonation. Departure of TFBB personnel from CDR was approximately September 3, 1957. The TFBB activities that may have resulted in exposure to residual radiation and the sources of residual radiation resulting in exposure were similar to those of the NTS Observer and Maneuver Troop EPG, and it is reasonable to consider including them in that EPG provided that they do not meet any other general exclusions (DTRA, 2011; Goetz et al., 1980; Ponton, 1981).

B-2 Basis for TFBB Dose Analysis

TFBB personnel were exposed to residual radiation from fallout of four shots in the forward test area during two rehearsals and the exercise on September 2, 1957. They were also exposed to radiation from fallout from Shot WILSON while at CDR. The exposure scenarios of individual TFBB members while conducting their activities were similar for all members of the task force. This EPG consists of three main cohorts, distinguished primarily by the timing of their completion of an infiltration course during the exercise on September 2. TFBB are distinguished here by whether they were in the early, middle, or late group of finishers of the infiltration course. For this analysis, the TFBB personnel that were in the last group of finishers form the basis for the generic highest-dose cohort scenario. The TFBB "latest finishers" scenario forms an adequate basis for the generic highest-dose cohort scenario for this analysis because the calculated film badge dose for this group was the largest of any TFBB test troop group. (DTRA, 2008; Goetz et al., 1980)

B-3 Highest-Dose Exposure Scenario

Three Exercise Desert Rock VII and VIII projects were conducted at Shot GALILEO. The largest of these was the Army troop test sponsored by HumRRO and conducted by TFBB. The HumRRO test involved disassembling and reassembling a rifle, clearing a practice minefield, and negotiating a combat course (infiltration course) in a contaminated area. These activities were conducted during two rehearsals (on August 23 and August 26), and during the exercise on September 2 (Goetz et al., 1980).

TFBB originally consisted of 160 enlisted men and seven officers. Those 100 men who had rifles were selected to participate in the HumRRO troop test. The remaining 67 were to assist HumRRO in various tasks in support of the troop test. Preliminary training and briefings, such as radiological safety training, were conducted at CDR starting on August 12 (their CDR arrival date). On August 23, TFBB personnel conducted their first activities in the forward test area, consisting of familiarization and rehearsal activities in the SMOKY test area. On August 26, the TFBB personnel returned to the forward area for baseline testing and the final rehearsal. Some members of TFBB witnessed Shot FRANKLIN PRIME on August 30 from News Nob, then returned to CDR. The entire task force witnessed Shot SMOKY on August 31 from News Nob, and then returned to CDR. Because of the distances from News Nob to the ground zeroes of these two shots there were no doses accrued by any member of TFBB during or after the detonations. Early on the morning of September 2, those TFBB personnel who had returned from weekend pass and were available (thought to be about 110 personnel) were transported to the forward NTS test area. They observed Shot GALILEO from an observer area that was on or near Mercury Highway, almost 5,000 yards from the GALILEO detonation. The observation area was beyond the area in which previous fallout may have been resuspended by the GALILEO detonation. TFBB personnel remained at the observation area for a short time, and then departed and moved by truck away from the GALILEO shot area toward the SMOKY test area. About two hours after GALILEO, they assembled in the parking area near the SMOKY test area. TFBB personnel then marched to the infiltration course, where they assembled into groups of four and five personnel. The groups moved through the course one group at a time, conducting various activities as they progressed through the course, including crawling under and between wire barriers. As the first group completed the course and returned to the parking area, the next group in line began the course. After the last group finished the course and had returned to the parking area, accompanied by test monitors, the troops loaded into trucks and were transported to CDR (Goetz et al., 1980; Ponton et al., 1981).

Assumptions similar to those used in the NTS Observer and Maneuver EPG were used for the analysis of TFBB doses, such as including a CDR descending fallout dose pathway, use of a higher breathing rate and outside occupancy, and departure from CDR one month after the end of the operation. In particular, the exposure pathways described in Table B-1 were incorporated.

Table B-1. Exposure Pathways for TFBB

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from fallout at locations of rehearsals and the exercise	TFBB personnel were exposed to BOLTZMANN, DIABLO, and SHASTA fallout during rehearsals on August 23 and 26, and BOLTZMANN, DIABLO, SHASTA, and SMOKY fallout during the exercise on September 2.	
Residual radiation from fallout at billet location	TFBB personnel were exposed to WILSON fallout at CDR from their arrival until their departure after the exercise (approximately 23 days).	Exposure to WILSON fallout at CDR for approximately 157 days instead of 22 days. The number of hours per day spent outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}. WILSON fallout exposure rate decay model is based on composite PLUMBBOB decay terms instead of on the default decay model using $(H{+}hours)^{-1.2}$. This increases the CDR doses by a factor of approximately 1.5.
INTERNAL		
Inhalation of resuspended fallout during rehearsals and the exercise	TFBB troops inhaled resuspended fallout during rehearsals and the exercise consistent with their activities, which included crawling over open terrain and also more typical activities such as walking over open terrain.	A resuspension factor of 10^{-4} m^{-1} that is applicable to troops that are crawling over open terrain (DTRA, 2008, ID01) was used for all activities during rehearsals instead of only during the time spent in the infiltration course.
Inhalation of descending fallout at billet location	Some early-arriving TFBB troops were at CDR during WILSON fallout there, thereby being exposed to descending WILSON fallout at CDR.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout at billet location	TFBB troops were subjected to inhalation of resuspended WILSON fallout at CDR from their arrival until their departure after the exercise (approximately 22 days).	Inhalation of resuspended WILSON fallout for approximately 157 days instead of for 22 days. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Number of hours spent outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
Incidental ingestion of contaminated soil/dust at billet location	TFBB troops incurred doses from incidental ingestion of soil and dust contaminated with WILSON fallout at CDR, from their arrival until their departure after the exercise (approximately 22 days).	Incidental ingestion of WILSON fallout at CDR for approximately 157 days instead of for 22 days.

B-4 Doses and Upper Bounds

The external and internal doses and corresponding upper-bound doses for TFBB are summarized in Table B-2. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the total dose. However, for the expedited processing analysis, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound external doses by multiplying the total external dose by an uncertainty factor of 3. The upper bound internal doses are calculated by multiplying the internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust, which are estimated as upper-bound doses (DTRA, 2010). The upper-bound doses in Table B-2 are not less than the upper-bound doses potentially accrued by any member of TFBB.

Table B-2. External and Internal Doses and Upper Bounds for Task Force BIG BANG

External Doses	**Dose (rem)**		**Upper-Bound Dose (rem)**	
Residual Gamma Radiation	2		6	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**Dose (rem)**		**Upper-Bound Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.001	0.002	0.005	0.02
Bone Surface	0.3	0.06	3	0.6
Brain	0.001	0.001	0.005	0.006
Breast	0.001	0.002	0.005	0.02
Stomach Wall	0.001	0.003	0.005	0.03
Small Intestine Wall	0.001	0.005	0.005	0.05
Upper Large Intestine Wall	0.001	0.02	0.005	0.2
Lower Large Intestine Wall	0.001	0.05	0.005	0.5
Kidney	0.002	0.001	0.02	0.01
Liver	0.06	0.02	0.6	0.2
Extrathoracic Region	0.003	0.06	0.03	0.6
Lung	0.008	0.2	0.08	2
Muscle	0.001	0.001	0.005	0.009
Pancreas	0.001	0.001	0.005	0.01
Red Marrow	0.02	0.006	0.2	0.06
Spleen	0.001	0.001	0.005	0.01
Testes	0.004	0.001	0.04	0.01
Thymus	0.001	0.002	0.005	0.02
Thyroid	0.001	0.08	0.005	0.8
Urinary Bladder Wall	0.001	0.002	0.005	0.02

* Initial gamma and neutron doses are treated separately and are based on the actual participant's exposure conditions at the time of detonations.

B-5 Comparison of TFBB Doses to NTS Observer and Maneuver EPG Doses

In order to support inclusion members of the TFBB in the larger NTS Observer and Maneuver Troop EPG, a comparison of the upper-bound doses has been made. The upper-bound doses for the NTS Observer and Maneuver Troop EPG are shown in Table 4, and the TFBB upper-bound doses are in Table B-2. Ratios of the respective upper-bound doses are shown in Table B-3. Ratios greater than 1.0 indicate that the TFBB dose is larger than the respective NTS Observer and Maneuver Troop EPG dose.

The dose ratios in Table B-3 show that the TFBB organ doses are similar to the corresponding NTS Observer and Maneuver Troop EPG doses. Almost all corresponding external and internal doses are within a factor of 2 of each other, and most TFBB doses are the same as or less than corresponding NTS Observer and Maneuver EPG doses. The largest dose difference is that for the external gamma doses, for which the TFBB upper-bound dose is 4 rem lower than the NTS Observer and Maneuver Troop EPG dose (ratio is 0.6). Differences in upper-bound internal doses are much smaller: the largest difference is 0.4 rem for the beta+gamma dose to bone surface (ratio is 3.0). The relatively large dose ratio of 6.7 for beta+gamma doses to liver represents a dose difference of only 0.17 rem.

For evaluating whether TFBB may be included in the NTS Observer and Maneuver Troop EPG, two important points relevant to the doses are considered. These points are important to an understanding of the total organ doses, and their subsequent use in the NTPR Program.

- The TFBB upper-bound external dose is 4 rem lower than that of the NTS Observer and Maneuver Troop EPG.
- For internal organ doses for which the TFBB dose is larger than the corresponding NTS Observer and Maneuver EPG dose, no TFBB dose is more than 0.4 rem larger than the corresponding NTS Observer and Maneuver Troop EPG dose.

Subsequent use of doses assigned to a veteran in the NTPR program involves an evaluation of the likelihood that the total organ dose is the cause of the veteran's disease. Because the large difference in external doses (4 rem) far exceeds the small differences in any organ doses (0.4 rem maximum), total organ doses for all organs in the NTS Observer and Maneuver EPG are much larger than those estimated for TFBB. The small differences in internal doses, especially at the level of these doses, are insignificant with regard to the likelihood that they might be the cause of a veteran's disease. Therefore, including the TFBB troops in the NTS Observer and Maneuver Troop EPG will not result in any meaningful underestimates of any TFBB organ doses.

Table B-3. Comparison of Doses for TFBB and NTS Observer & Maneuver Troop EPG

	Upper-bound Dose Ratios (TFBB / NTS ObsMan EPG)	
External Dose Ratio	0.6	
Internal Dose Ratios for NTPR Standard Organs	**Alpha**	**Beta + Gamma**
Adrenals	0.6	1.0
Bone Surface	0.6	**3.0** (0.4)*
Brain	0.6	1.0
Breast	0.6	**2.0** (0.01)
Stomach Wall	0.6	0.6
Small Intestine Wall	0.6	0.7
Upper Large Intestine Wall	0.6	1.0
Lower Large Intestine Wall	0.6	**1.2** (0.1)
Kidney	1.0	**1.1** (0.001)
Liver	0.6	**6.7** (0.17)
Extra-Thoracic Region	0.6	0.9
Lung	0.8	1.0
Muscle	0.6	1.0
Pancreas	0.6	0.5
Red Marrow	0.7	**1.2** (0.01)
Spleen	0.6	1.0
Testes	0.7	**2.0** (0.005)
Thymus	0.6	1.0
Thyroid	0.6	1.0
Urinary Bladder Wall	0.6	1.0

* For dose ratios greater than 1.0, the amount (rem) that the TFBB dose exceeds the NTS Observer Maneuver EPG dose is shown in parentheses.

B-6 Appendix B References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2*, Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a.* DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Goetz, J. L., McGahan, J. T., Kaul, D., McRaney, W.K., Klemm, J., 1980. *Analysis of Radiation Exposure For Task Force BIG BANG, Shot GALILEO, Exercise Desert Rock VII – VIII, Operation PLUMBBOB.* DNA 4772F, Defense Nuclear Agency, Washington, DC. April 9.

Ponton, J., Wilkinson, M., Striegel, J., Collins, B., 1981. *Shot GALILEO, A Test of the PLUMBBOB Series, 2 September 1957.* DNA 6001F, Defense Nuclear Agency, Washington, DC. February 27.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

NTS Support Troops with no Forward Area Activities (1951–1962)

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: NTS Support Troops with no Forward Area Activities (1951–1962)

1. Description of the Expedited Processing Group

This Expedited Processing Group (EPG) generally consists of Army, Navy, Marine Corps and Air Force participants who were stationed at one of the NTS billet locations that housed troops supporting routine operations at the NTS during the period 1951–1962. Specifically, this EPG consists of military participants that were stationed at Camp Mercury, Camp Desert Rock (CDR), Indian Springs Air Force Base (AFB), or Nellis AFB and did not conduct any activities in any of the forward NTS test areas during their assignment. Most personnel in this EPG were assigned to one of the billet locations during a single operational period from 1951 through 1962. Additional personnel in this EPG include participants assigned to one of the billet locations during an interoperation period following one of the eight operations. Only those individuals whose participation did not require them to routinely enter the NTS forward test area are included in this EPG. For the purpose of this EPG, "NTS forward NTS test area" means test areas north of News Nob near the NTS Area 6 Control Point, and the Frenchman Flat test area east of the Mercury Highway in NTS Area 5 (Figure 1). Although not all EPG members were stationed at their billet location for the same period of time, activities that may have resulted in exposure to residual radiation and the sources of residual radiation resulting in exposure of these troops were similar. Therefore, it is reasonable to include operational and interoperational participants from all NTS test series into a single EPG.

The eight relevant test series that were conducted at the NTS from 1951 to 1962 and their operational periods are shown in Table 1. An interoperational period is generally defined as starting on the day after an operation and lasting until the day before the start of the following operation. The 1-year period following Operation DOMINIC-II is also used here as an interoperation period. Three primary locations were used to house personnel supporting the NTS tests: Camp Mercury, CDR, and Indian Springs AFB. Camp Mercury was located at the southern boundary of the NTS, and was the base of management operations for the joint civilian-military planning and management organization. It was a permanent installation built by the Atomic Energy Commission after Operation RANGER in 1951, and provided office and living quarters, laboratory facilities, and warehouses for the temporary and permanent personnel participating in various NTS test activities. Personnel were housed in dormitories, huts, and trailers. The population of Camp Mercury during operational periods was typically no more than a few thousand personnel. Camp Desert Rock served as headquarters of the Sixth Army Desert Rock exercises, and was located just south of the southern boundary of the NTS (about 2 miles southwest of Camp Mercury). Camp Desert Rock was established during Operation BUSTER-JANGLE, and consisted of Quonset huts and semi-permanent structures augmented by trailers and tents as necessary. The camp population varied considerably, depending on the schedule of weapons tests and associated troop maneuvers. During test periods, CDR often housed several thousand DOD personnel assigned to participate in the nuclear weapons tests. When tests were not being conducted, however, fewer than 100 people maintained the camp. Indian Springs AFB was approximately 20 miles east of Camp Mercury, and was the principle staging base for Air

Force Special Weapons Center (AFSWC) aircraft. Permanent facilities provided housing; messing; and security and air base operations for the AFSWC support activities. Typically between 200 and 400 personnel were assigned to ISAFB for test support. A fourth location, Nellis AFB, was located about 60 miles east of the NTS and was used as the headquarters for the Atomic Energy Commission during Operation RANGER (1951). Other locations, such as Kirtland AFB in New Mexico, served as staging and decontamination areas for Air Force aircraft; however, personnel at these locations are typically excluded from this EPG based on their activities (Harris et al., 1981; Maag et al., 1982; Ponton et al., 1981; Ponton et al., 1982a-d; Ponton et al., 1983).

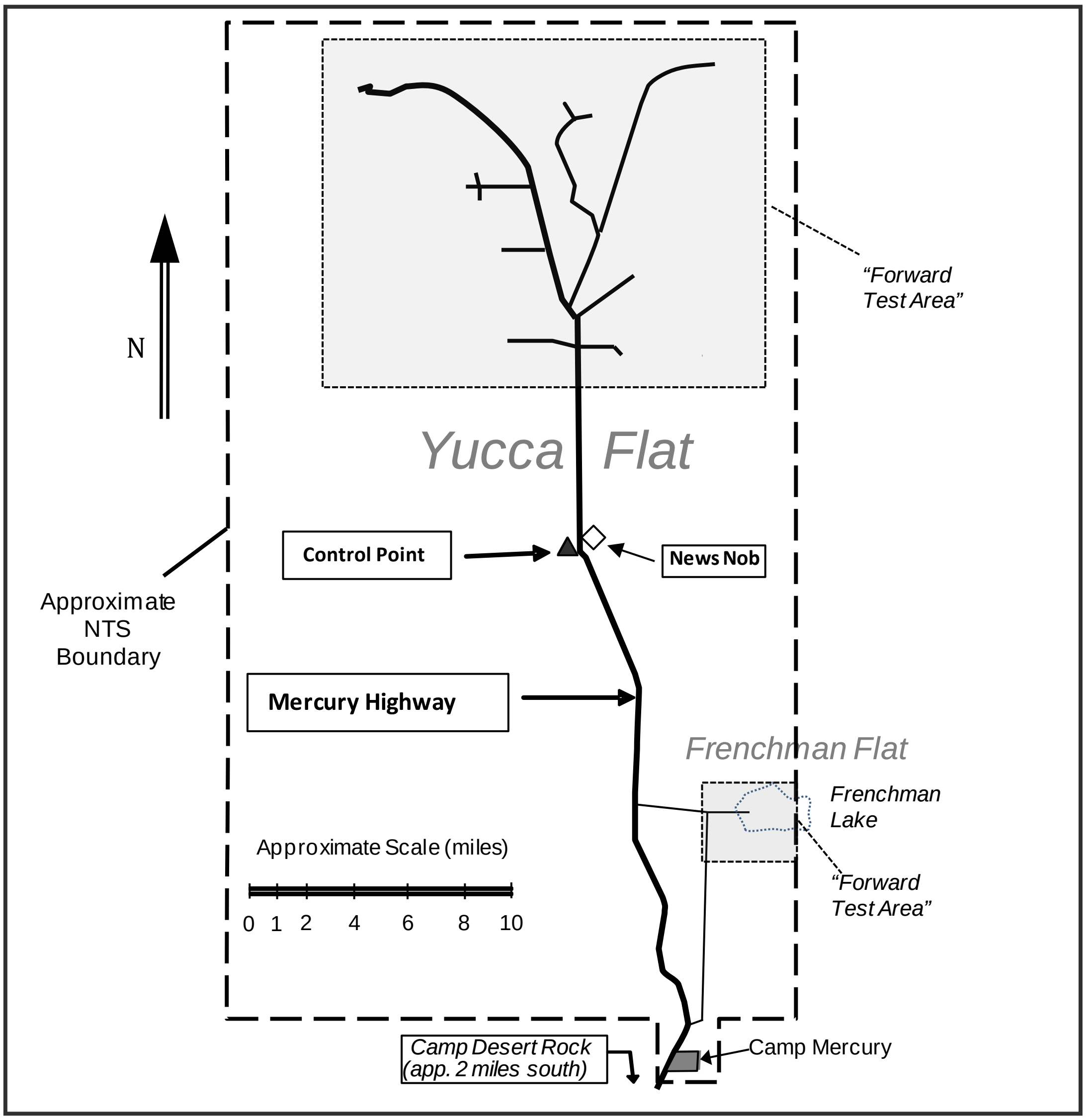

Figure 1. Schematic of NTS 1951-1962 Indicating Approximate Locations of Forward Test Areas

Table 1. NTS Support Billeting Locations during the NTS Operations

NTS Operation	Operational Period	Camp Mercury	Camp Desert Rock	Indian Springs AFB
RANGER*	Jan 27–Feb 6, 1951			✓**
BUSTER-JANGLE	Oct 22–Dec 20, 1951	✓	✓	✓
TUMBLER-SNAPPER	Apr 1–Jun 20, 1952	✓ ✓§	✓ ✓	✓ ✓
UPSHOT-KNOTHOLE	Mar 17–Jun 20, 1953	✓ ✓	✓ ✓	✓ ✓
TEAPOT	Feb 18–Jun 10, 1955	✓ ✓	✓ ✓	✓ ✓
PLUMBBOB	May 28–Oct 22, 1957	✓ ✓	✓ ✓	✓ ✓
HARDTACK-II	Sep 19–Oct 31, 1958	✓	†	✓
DOMINIC-II	Jul 6– Aug 15, 1962	✓	‡	✓

* Personnel were also housed at the main Atomic Energy Commission headquarters at Nellis AFB located near Las Vegas, NV during RANGER.

** "✓",indicates that personnel were housed at the location, but no fallout was detected at the location during the operation.

§ "✓ ✓" indicates that personnel were housed at the location and that fallout was detected at the location during the operation.

† Desert Rock Exercises were not conducted during HADRDTACK-II, and it is not known if personnel were stationed at CDR.

‡ Desert Rock Exercises were not conducted during DOMINIC-II, however Army personnel may have been stationed at CDR to support Exercise IVY.

As described above, this EPG generally consists of military participants providing support to NTS operations that were stationed at Camp Mercury, CDR, Indian Springs AFB, or Nellis AFB during or after any one of the eight NTS operations, and that did not conduct any activities in any of the forward NTS test areas during their assignment. However, doses in this EPG should not be assigned to any participant for whom any of the general exclusions for NTS personnel are applicable. There are no specific exclusions for this EPG.

2. Basis of Dose Analysis for NTS Support Troops with no Forward Area Activities

To estimate bounding doses for all NTS support troops, an exposure scenario was developed based on activities of the cohort group that received the highest external residual radiation dose and corresponding internal doses. This cohort is referred to as the “highest-dose cohort”. Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a “highest-dose cohort” because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

For this EPG, the support troops stationed at CDR during Operation TEAPOT form the basis for the generic highest-dose cohort scenario. The TEAPOT CDR scenario forms an adequate basis for the generic highest-dose cohort scenario for this EPG for three primary reasons (DTRA, 2008):

- This group received an external gamma dose from residual radiation that was comparable to the largest dose received by any NTS support troop cohort.
- This group received internal organ doses from residual radiation that were significantly larger than the highest doses received by any other NTS support troop cohort.
- The radiation sources of exposure for this group are well-documented and are representative of other NTS support troops.

As explained below, several dose components and assumptions were added to the documented TEAPOT CDR scenario to produce EPG doses. The basic TEAPOT CDR scenario is described directly below, followed by a description of additional maximizing dose components and assumptions.

3. Highest-Dose Cohort Scenario: CDR Support Troops at Operation TEAPOT

Approximately 11,000 Department of Defense personnel, both military and civilian, participated in various activities at Operation TEAPOT. These Department of Defense personnel participated in administration and support activities, Test Group military effects and diagnostic activities, DOD operational training projects, EDR programs and support, and air support activities. Most of these participants, approximately 8,000, took part in the EDR training and test program at TEAPOT; this number included about 2,000 DOD personnel who were required to administer and support the exercises from the EDR headquarters at CDR. The remaining DOD personnel assisted in the administration of Operation TEAPOT or took part in the scientific, diagnostic, and operational training programs (Ponton et al., 1981).

Fallout at CDR is the only source of radiation exposure for CDR support troops. As shown in Table 1, fallout was deposited at support troop billeting locations during operations TUMBLER-SNAPPER (1952), UPSHOT-KNOTHOLE (1953), TEAPOT (1955), and PLUMBBOB (1957). No more than one shot deposited fallout resulting in an exposure rate of greater than 0.001 roentgen per hour (R hr^{-1}) at any location during any one of these test series. Fallout from Shot SMOKY (Operation PLUMBBOB) at Indian Springs AFB and Shot POST (Operation TEAPOT) at CDR resulted in similar measured exposure rates that were the highest rates and integrated exposures at any billeting location. Fallout from Shot POST could have resulted in internal organ doses that are from 2–3 orders of magnitude larger than those from Shot SMOKY or any other fallout shot. Therefore, external doses from deposited POST fallout at CDR were calculated for this EPG, as well as internal doses from inhalation of descending and subsequently resuspended POST fallout at CDR. CDR TEAPOT support troops were exposed to residual radiation from POST fallout from April 9 until their departure from CDR, nominally shortly after the last shot of the operation (May 15, 1955). The residual radiation exposure rates of POST fallout at CDR are shown in Figure 2.

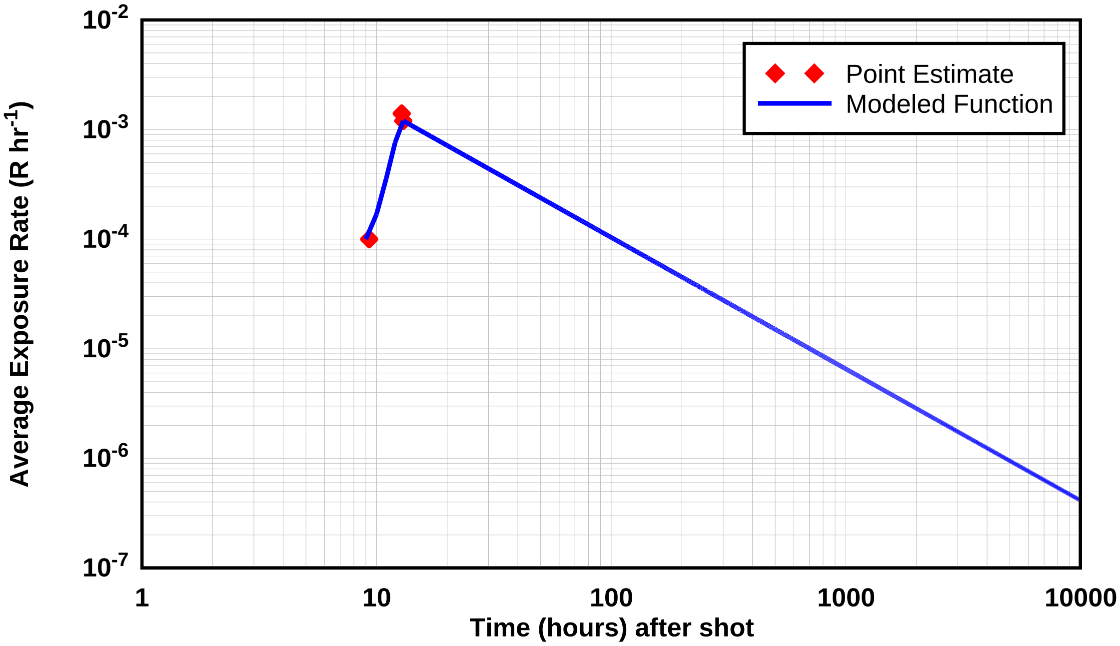

Figure 2. Residual Radiation Exposure Rates Encountered by TEAPOT CDR Support Troops while at CDR

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to or substituted into the high-dose TEAPOT CDR scenario cohort analysis.

- Because some CDR support troops in this EPG may have been stationed at CDR for extended periods of time, a period of assignment at CDR lasting until 92 days after Shot POST was used. This end date corresponds to one month after the end of Operation TEAPOT instead of until the end of the operation (62 days after POST). This increases the exposure to fallout deposited at CDR.
- The number of hours spent outdoors was increased from 14.4 to 16 hr day^{-1}, while 8 hours were spent indoors in a tent for sleeping, cleaning and eating. This increases both the internal and external doses from fallout at CDR.
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50 percent light activity and 50 percent moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 2. The values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for the TEAPOT CDR Support Troops

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from fallout at billet location	CDR support troops were exposed to POST fallout at CDR from POST shot day until their departure.	Assignment at CDR following Shot POST is approximately 92 days instead of 62 days. The number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
INTERNAL		
Inhalation of descending fallout at billet location	CDR support troops were exposed to descending POST fallout at CDR.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}
Inhalation of resuspended fallout at billet location	CDR support troops were subjected to inhalation of resuspended POST fallout at CDR from POST shot day until their departure.	Inhalation of resuspended POST fallout for approximately 92 days instead of for 62 days. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}. Number of hours spent outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
Incidental ingestion of contaminated soil/dust at billet location	CDR support troops incurred doses from incidental ingestion of soil and dust contaminated with POST fallout at CDR, from POST shot day until their departure (approximately 62 days).	Incidental ingestion of POST fallout at CDR for approximately 92 days instead of 62 days.

Table 3. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{Arrived}$	CDR start date[time] (day of fallout at CDR)	9 Apr 55[1348]
$Date_{Departed}$	CDR end date[time] (one month after end of TEAPOT)	10 Jul 55[1200]
EXTERNAL DOSE		
Int_{CDR}	Peak POST fallout exposure rate at CDR	0.0014 R hr^{-1} at H+12.8 (DTRA, 2008, Appendix C-6)
Tpeak	H+ time of peak exposure rate	H+12.8
-	Duration of exposure to POST fallout at CDR	2216 hr
F_{os}	Fraction of time spent outside at CDR	0.67 (= 16/24)
PF_t	Protection factor while indoors at CDR, assumed to be inside a tent	1.5 (DTRA, 2010, ED02)
TWSF	Time-Weighted Shielding Factor for time at CDR (calculated using F_{os} and PF_t)	0.889
λ	Default fallout exposure rate decay exponent for times less than 6 months after shot (used as $[H+hours]^{\lambda}$)	−1.2
λ_{6mos}	Default fallout exposure rate decay exponent for times greater than 6 months after shot (used as $[H+hours]^{\lambda}$)	−2.2
F_B	Film badge equivalent conversion factor	0.7 rem R^{-1} (DTRA, 2010)
UF_{ext}	Upper bound factor for external doses	3 (DTRA, 2010, SM01)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (DTRA, 2010, SM01)
F_{os}	Fraction of time spent outside at CDR	0.67 (= 16/24)
q_{ing}	Soil ingestion rate	500 mg day^{-1} (DTRA, 2010, SM01
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (DTRA, 2010, SM01)
DCF_{Inh} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (selected maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM01)
UF_{int}	Upper bound factor for internal doses	10 (DTRA, 2010, SM01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound EPG doses for NTS Support Troops with no Forward Area Activities are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for expedited processing upper-bound doses, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound external doses by multiplying the total external dose by an uncertainty factor of 3. The upper bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from the incidental ingestion of soil and dust, which are estimated as upper-bound doses (DTRA, 2010). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for NTS Support Troops with no Forward Area Activities

External Doses	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
Residual Gamma Radiation	0.04		0.1	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organ	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.001	<0.001	0.007	<0.001
Bone Surface	0.4	0.005	4	0.05
Brain	0.001	<0.001	0.007	<0.001
Breast	0.001	<0.001	0.007	<0.001
Stomach Wall	0.001	0.001	0.007	0.006
Small Intestine Wall	0.001	0.001	0.007	0.009
Upper Large Intestine Wall	0.001	0.003	0.007	0.03
Lower Large Intestine Wall	0.001	0.006	0.007	0.05
Kidney	0.002	<0.001	0.02	<0.001
Liver	0.08	0.002	0.8	0.02
Extra-Thoracic Region	0.004	0.009	0.04	0.09
Lung	0.008	0.009	0.08	0.09
Muscle	0.001	<0.001	0.007	<0.001
Pancreas	0.001	<0.001	0.007	<0.001
Red Marrow	0.02	<0.001	0.2	0.004
Spleen	0.001	<0.001	0.007	<0.001
Testes	0.005	<0.001	0.05	0.001
Thymus	0.001	<0.001	0.007	0.001
Thyroid	0.001	0.02	0.007	0.2
Urinary Bladder Wall	0.001	<0.001	0.007	0.003

* Initial gamma and neutron doses are treated separately and are based on the actual participant's exposure conditions at the time of detonations.

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

Harris, P.S., Lowery, C., Nelson, A., Obermiller, S., Ozeroff, W.J., and Weary, S.E., 1981. *PLUMBBOB Series, 1957*. DNA 6005F, Defense Nuclear Agency, Washington, DC. September 15.

Maag, C., Rohrer, S., and Shepanek, R., 1982. *Operation RANGER, Shots ABLE, BAKER, EASY, BAKER-2, FOX, 25 January – 6 February 1951*. DNA 6022F, Defense Nuclear Agency, Washington, DC. February 26.

Ponton, J., Maag, C., Wilkinson, M., and Shepanek, R., 1981. *Operation TEAPOT, 1955*. DNA 6009F, Defense Nuclear Agency, Washington, DC. November 23.

Ponton, J., Maag C., Barrett, M.F., and Shepanek, R., 1982a. *Operation TUMBLER-SNAPPER, 1952*. DNA 6019F, Defense Nuclear Agency, Washington, DC. June 14.

Ponton, J., Massie, J., Maag C., Shepanek, R., and Rohrer, S., 1982b. *Operation UPSHOT-KNOTHOLE, 1953*. DNA 6014F, Defense Nuclear Agency, Washington, DC. January 11.

Ponton, J., Rohrer, S., Maag, C., Shepanek, R., and Gravitis, I., 1982c. *Operation HARDTACK II, 1958*. DNA 6026F, Defense Nuclear Agency, Washington, DC. December 3.

Ponton, J., Rohrer, S., Maag, C., Shepanek, R., and Massie, J., 1982d. *Operation BUSTER-JANGLE, 1951*. DNA 6023F, Defense Nuclear Agency, Washington, DC. June 21.

Ponton, J., Maag, C., Rohrer, S., Shepanek, R., 1983. *Operation DOMINIC II, Shots LITTLE FELLER II, JOHNIE BOY, SMALL BOY, Little FELLER I, 7 July – 17 July, 1962*. DNA 6027F, Defense Nuclear Agency, Washington, DC. January 31.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4*. DTRA-TR-07-11 Defense Threat Reduction Agency, Fort Belvoir, VA. May.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation UPSHOT-KNOTHOLE 2nd Marine Corps Provisional Atomic Exercise Brigade

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

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Expedited Processing Group: 2nd Marine Corps Provisional Atomic Exercise Brigade

1. Description of the Expedited Processing Group

The 2nd Marine Corps Provisional Atomic Exercise Brigade (2MCPAEB) Expedited Processing Group (EPG) consists of approximately 2,000 Marine Corps personnel who were members of the 2MCPAEB at the Nevada Test Site (NTS) during Operation UPSHOT-KNOTHOLE in 1953.

The 2MCPAEB conducted the Marine Corps portion of Exercise Desert Rock V (EDR V) at Shot BADGER. Four primary units composed the 2MCPAEB: a Brigade Headquarters group (HQ); 1st Battalion, 8th Marine Regiment (1/8); 2nd Battalion, 3rd Marine Regiment (2/3), and Marine Helicopter Transport Group 16. The two battalions were reinforced by personnel from several unidentified units, including a howitzer battery; tank, engineer, and ordnance maintenance platoons; air control personnel; naval gunfire liaison personnel; and an aviation detachment. While assigned to Camp Desert Rock (CDR) in April, 1953, 2MCPAEB personnel observed three detonations; participated in a rehearsal and an exercise; and assessed equipment damage at the NTS (Frank et al., 1982; Massie et al., 1982).

As described above, this EPG consists of members of 2MCPAEB. Specifically, the EPG includes participants assigned to or participating as a member of a company in one of the battalions (1/8 or 2/3), or HQ. This includes 2MCPAEB radiation monitors whose only monitoring activities involved those with 2MCPAEB on April 16-19, 1953. Doses in this EPG should not be assigned to any 2MCPAEB participant for whom any of the general exclusions for NTS personnel are applicable. In addition to the general exclusions, the following individuals, units, or cohorts are excluded from expedited processing under this EPG:

- Personnel in Marine Helicopter Transport Group 16 that conducted air operations during the 2MCPAEB activities at Shot BADGER.
- Personnel in the 2MCPAEB Provisional Helicopter Atomic Test Unit that participated in the Operational Helicopter Test Program at several shots including Shot BADGER.

2. Basis of Dose Analysis for 2MCPAEB

To estimate bounding doses for all 2MCPAEB personnel in this EPG, an exposure scenario was developed based on activities of the cohort that received the highest external residual radiation dose. This cohort is referred to as the “highest-dose cohort.” Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a “highest-dose cohort” because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

2MCPAEB personnel were exposed to a complex radiation environment during and following their maneuver in the BADGER test area. Exposures during this time contributed the largest component of their total doses. The available iso-contour plots of the BADGER test area are inconsistent, reflecting the complexity and also suggesting that personnel had difficulty making accurate measurements and interpreting the readings. Therefore, the previously-reconstructed doses that are based on published survey data (Frank et al., 1982) were not used as the basis for determination of the highest-dose cohort. Instead, available film badge records were used as described below. The next section describes the use of film badge records for estimation of the EPG doses. (Brown, 1953; Frank et al., 1982; DTRA, 2010a)

The 2MCPAEB EPG comprises nine cohorts, consisting of the four Companies in each of the two participating battalions, plus HQ. Each of these cohorts was a cohesive unit for which all members conducted similar activities. Approximately two film badges were issued to each platoon of 2MCPAEB. Representative film badge records are available for all cohorts (Table 1), and these records form the basis for identifying the highest-dose cohort. Based on the film badge records (DTRA, 2010a), Company C of 1/8 (C/1/8) is the highest dose cohort because both the average and highest film badge readings for this unit are the highest of all cohorts in the EPG (DTRA, 2008; Frank et al., 1982).

Table 1. Dosimetry Records for 2MCPAEB Cohorts

Cohort	Number of Film Badge Records	Film Badge Readings (R)		
		High	Low	Average
HQ	21	6.60	3.40	4.14
D/2/3	10	5.20	3.33	3.96
E/2/3	5	3.35	2.59	2.92
F/2/3	12	5.18	2.70	3.43
HS/2/3	8	5.12	3.00	3.52
A/1/8	5	6.20	2.98	4.16
B/1/8	6	3.50	2.00	2.96
C/1/8	4	7.10	4.20	5.42
HS/1/8	6	3.70	1.00	2.30

The activities of C/1/8 form an adequate basis for the generic highest-dose cohort scenario for this EPG for two primary reasons:

- The high and mean film badge readings for this cohort were both higher than for any other 2MCPAEB cohort.
- This cohort received an average external gamma dose from fallout that was similar to other cohorts in the EPG.

As explained below, several dose components and assumptions were added to the documented C/1/8 scenario (Frank et al., 1982) to produce doses that are bounding for all EPG members. The basic C/1/8 scenario is described directly below, followed by a description of the additional maximizing assumptions.

3. Highest-Dose Cohort Scenario: 1/8 Company C

A generic high-sided exposure scenario was developed based on activities of C/1/8 personnel (Brown, 1953; DTRA, 2008; Frank et al., 1982; Massie et al., 1982). The four 1/8 companies arrived at CDR on April 13, 1953, and the first subsequent 2MCPAEB activity in the forward area was a full rehearsal conducted on April 16. C/1/8 personnel then participated in the maneuver immediately after the BADGER detonation on April 18. Their maneuver activities ended prematurely after marching about 500 yards to the 3500-yard line, where they encountered high radiation levels. At this point they halted, reversed their course and returned to the BADGER trench area where they remained for the remainder of the maneuver. Other 2MCPAEB personnel completed the maneuver, including one unit (E/2/3) that conducted an air assault in Marine helicopters. After completion of the maneuver, all 2MCPAEB units except C/1/8 conducted a tour of the BADGER display area, during which they may have reached as far forward as the displays located 500 yards from the BADGER ground zero. 2MCPAEB personnel departed from the BADGER test area for CDR within an hour after completion of the display area tour. Sometime after the maneuver, a 2MCPAEB damage evaluation team (possibly including C/1/8 personnel) inspected and documented the condition of the equipment display items. Because of possible Rad-Safe restrictions, this activity may not have taken place until April 19, the day after Shot BADGER. C/1/8 was scheduled to depart from CDR on April 19, and all units were scheduled to depart by April 21. (Brown, 1953; DTRA, 2008; Frank et al., 1982; Massie et al., 1982)

Although C/1/8 did not complete the maneuver, they received a higher external dose than other 2MCPAEB units. The higher dose was due in part to radiation from the stem of the BADGER nuclear cloud that passed near their location at the time they halted their advance. Because they returned to the trenches without completing the maneuver, they were not subjected to the same potential for inhalation of resuspended fallout as were other units. However, diagnostic runs conducted for this EPG analysis show that the magnitude of the differences in their film badge readings (Table 1), is much greater than any internal organ doses they may have received from inhalation of resuspended BADGER fallout during the maneuver.

Because of the uncertainty in the radiation environments C/1/8 encountered on BADGER shot day, available film badge records were used for estimation of the EPG doses. The C/1/8 mean film badge reading of 5.42 R was used as the highest-dose cohort dose for all activities and sources over the period April 18–19, 1953. Note that although some 2MCPAEB personnel received doses higher than this (Table 1), use of the higher doses would unreasonably high-side the EPG doses. The use of the mean C/1/8 reading of 5.42 rem as the basis for the external dose for this EPG is justified by considering that the application of the upper-bound factor of 3 results in an upper-bound EPG external gamma dose of over 16 rem. This upper-bound dose far exceeds the highest upper-bound dose of approximately 11.4 rem that would be obtained by using a film badge dose of 7.10 rem (Table 1) and the upper-bound film badge factor that would be used in a Radiation Dose Analysis based on the available film badge readings. (DTRA, 2010b, ED01; Frank et al., 1982; NRC, 1989; SAIC, 2006)

During the period April 18–19, C/1/8 conducted several activities where they accrued doses. In order to unravel the film badge dose components for the assessment of internal doses, the activities and estimated doses for three of the four primary contributors are listed below (Frank et al., 1982); the small contribution from BADGER initial gamma radiation (<0.01 rem) is not included.

- Radiation from NANCY fallout in the BADGER trench area on April 18: 0.03 rem.
- Radiation from the BADGER stem during the aborted maneuver on April 18: 2 rem.
- Radiation from BADGER fallout during the damage evaluation on April 19: 1 rem.

The fourth primary dose contributor—deposited BADGER fallout during the aborted maneuver— was assumed to be the remainder of the mean film badge reading. The dose of 2.39 rem for this source was thus determined by subtracting the sum of the first three dose components (3.03 rem) from the mean film badge reading of 5.42 rem.

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to or substituted into the highest-dose cohort analysis. These are described below.

- Some members of the 2MCPAEB were stationed at CDR longer than the duration of about one week typically used for 2MCPAEB Radiation Dose Assessments. The period of assignment at CDR used for the EPG scenario is defined as starting in early April and lasting until after the end of Operation UPSHOT-KNOTHOLE. The start date precedes BADGER fallout at CDR, and the end date is one month after the official end of UPSHOT-KNOTHOLE (VA, 2010). This extended period of assignment lengthens the time of exposure to BADGER fallout deposited at CDR relative to a routine 2MCPAEB Radiation Dose Assessment.
- The number of hours spent outdoors at CDR was increased from the default of 14.4 to 16 hr day^{-1}, while 8 hours each day were spent in a tent while sleeping, cleaning and eating. This affects the internal and external doses from BADGER fallout at CDR.
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50 percent light activity and 50 percent moderate activity Weitz, et al. (2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.
- The internal doses received by 2/3 and HQ personnel from the inhalation of blast-resuspended fallout are included in the EPG scenario for all EPG members. Doses from inhalation of blast-driven resuspended fallout from Shot HOW (TUMBLER-SNAPPER) and NANCY (UPSHOT-KNOTHOLE) during the maneuver and display area tour are included. These doses are included in the highest-cohort analysis as an additional dose component to ensure that estimated internal organ doses are bounding for all EPG personnel. The blast-driven resuspension doses are based on the generic organ doses from blast effects for a BADGER maneuver participant, calculated using the current recommended effective resuspension factors for blast effects (DTRA, 2008; Kocher et al., 2009).
- The internal doses received by E/2/3 personnel from the inhalation of NANCY and BADGER fallout resuspended by helicopter rotor wash are included in the EPG scenario for all EPG members. These doses are included in the highest-cohort analysis as an additional dose component to ensure that estimated internal organ doses are bounding for all EPG

personnel. The rotor wash resuspension doses are based on the recommended resuspension factor in DTRA (2010b).

- The earliest possible arrival time at CDR following the 2MCPAEB maneuver is included in the EPG scenario for all EPG members. This is incorporated into the highest-cohort analysis to increase the period of time used for inhalation of descending BADGER fallout, and thus maximize internal organ doses.
- Doses from participation in the damage evaluation activity are included in the EPG scenario for all EPG members, although the damage evaluation team involved only a few personnel. This exposure pathway is included in the highest-cohort analysis to ensure that estimated internal organ doses bound the internal doses for all EPG members.

Exposure pathways and maximizing factors for the 2MCPAEB EPG are described in Table 2. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 3.

Table 2. Exposure Pathways for the 2MCPAEB

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Residual radiation from fallout at the BADGER test area.	C/1/8 personnel were exposed to NANCY fallout during the rehearsal, and NANCY and BADGER fallout during the abbreviated maneuver. The damage evaluation team was exposed to NANCY and BADGER fallout during the damage evaluation activity.	.
Residual radiation from the stem of the BADGER fireball in the forward area.	C/1/8 personnel received a dose from this source while moving forward to a location about 500 yards from the trenches.	
Residual radiation from fallout at billet location.	C/1/8 personnel were exposed to BADGER fallout at CDR from the time of their arrival after the maneuver until their departure (approximately 3 days).	Assignment at CDR following BADGER is approximately 93 days instead of 3 days. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
INTERNAL		
Inhalation of resuspended fallout during forward-area activities.	C/1/8 personnel inhaled resuspended fallout during the rehearsal and abbreviated maneuver. 2/3 and HQ personnel inhaled resuspended fallout during the entire maneuver and display area tour. The damage evaluation team inhaled resuspended fallout during the damage evaluation activity.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of descending fallout at CDR.	C/1/8 personnel were exposed to descending BADGER fallout at CDR for approximately 5.5 hours.	Inhalation of descending BADGER fallout at CDR for 7.6 hours instead of 5.5 hours. Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.

Table 2. Exposure Pathways for the 2MCPAEB (cont.)

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
INTERNAL		
Inhalation of blast-driven resuspended fallout.	2/3 and Brigade HQ personnel inhaled blast-driven resuspended fallout during the maneuver and display area tour.	Breathing rate is 2 $m^3 hr^{-1}$ instead of 1.2 $m^3 hr^{-1}$.
Inhalation of fallout resuspended by helicopter operations.	E/2/3 personnel inhaled helicopter-resuspended fallout during loadings/unloading conducted during the rehearsal and maneuver.	Breathing rate is 2 $m^3 hr^{-1}$ instead of 1.2 $m^3 hr^{-1}$.
Inhalation of resuspended fallout at billet location.	C/1/8 personnel inhaled resuspended BADGER fallout at CDR from the time of their return after the maneuver until their departure (approximately 3 days).	Assignment at CDR following BADGER is approximately 93 days instead of 3 days. Breathing rate is 2 $m^3 hr^{-1}$ instead of 1.2 $m^3 hr^{-1}$. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
Incidental ingestion of contaminated soil/dust at billet location.	C/1/8 personnel incurred doses from incidental ingestion of soil and dust contaminated with BADGER fallout at CDR, from the time of their return after the maneuver until their departure (approximately 3 days).	Assignment at CDR following BADGER is approximately 93 days instead of 3 days.

Table 3. Input Parameter Values and for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{ArrCDR}$	Date [time] of arrival at CDR	5 Apr 53[0800]
$Date_{ArrCDRpostman}$	Date [time] of return to CDR after the maneuver	18 Apr 53[0900]
$Date_{DepCDR}$	Date [time] of departure from CDR (1 month after the end of UPSHOT-KNOTHOLE)	20 Jul 53[1200]
$Tpkint_{BD}$	Time of peak BADGER fallout exposure rate at CDR	BADGER H+12
Duration	Durations of various 2MCPAEB activities:	
	Rehearsal	3.5 hr
	Pre-shot time at BADGER trenches	1.8 hr
	Maneuver and waiting at trench area	2.3 hr
	Damage Evaluation	2.3 hr
	Duration of exposure to descending BADGER fallout at CDR	7.6 hr
	Duration of each exposure to highly-resuspended fallout in the vicinity of helicopter operations	3 min

Table 3. Input Parameter Values and for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
EXTERNAL DOSE		
$BadgeData_{18CoC}$	Average C/1/8 film badge reading	5.42 rem (DTRA, 2010a)
$Dose_{stem}$	Portion of average C/1/8 film badge reading attributable to passing BADGER stem	2.0 rem
$Dose_{DE}$	Portion of average C/1/8 film badge reading attributable to damage evaluation activity	1.0 rem
$Dose_{NAN}$	Portion of average C/1/8 film badge reading attributable to NANCY fallout in the BADGER trench area on April 18	0.03 rem
$Int_{NY.BDtrenches}$	Residual NANCY fallout exposure rate during rehearsal and pre-maneuver time in trenches	0.02 R hr^{-1}
$Intpeak_{BD.CDR}$	Peak BADGER fallout exposure rate at CDR	0.0004 R hr^{-1} at H+12
F_{os}	Fraction of time spent outside at CDR	16/24 = 0.67
PF_t	Protection factor while indoors at CDR, assumed to be inside a tent	1.5
TWSF	Time-Weighted Shielding Factor for time at CDR (calculated using F_{os}, F_{tent}, and PF_t)	0.889
λ	Default fallout decay exponent for times less than 6 months after shot (used as $[\text{H+hours}]^{\lambda}$)	−1.2
F_B	Film badge equivalent conversion factor	0.7 rem R^{-1} (DTRA, 2010b)
UF_{ext}	Upper bound factor for external doses	3 (DTRA, 2010b, SM UA01)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (SM ID01 of DTRA, 2010b)
K_{helo}	Resuspension factor for helicopter operations	10^{-3} m^{-1} (SM ID01 of DTRA, 2010b)
K_{pc}, K_{bw}	Resuspension factors for fallout in precursor (thermal pulse) region (0–1280 yd) or blast wave region (1280–2530 yd) due to detonation effects	$K_{pc} = 1 \times 10^{-3}$ m^{-1} $K_{bw} = 1 \times 10^{-4}$ m^{-1} (SM ID01 of DTRA, 2010b; Appendix C-5 of DTRA, 2008)
Num_{helo}	Total number of exposures to highly-resuspended fallout while loading and unloading from helicopters	4

Table 3. Input Parameter Values and for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
INTERNAL DOSE		
F_{os}	Fraction of time spent outside at CDR	16/24 = 0.67
q_{ing}	Soil ingestion rate	500 mg day^{-1} (SM ID01 of DTRA, 2010b)
ρ_{soil}	Soil bulk density	1.3 g cm^{-3} (SM ID01 of DTRA, 2010b)
DCF_{Inh} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (selected maximum values among particle sizes of 1–10 μm for inhalation) (Raine et al., 2007; SM ID01 of DTRA, 2010b)
UF_{int}	Upper bound factor for internal doses	10 (SM UA01 of DTRA, 2010b)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for 2MCPAEB are summarized in Table 4. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for expedited processing doses, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound external doses by multiplying the total external dose by an uncertainty factor of 3. The upper-bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except doses from inhalation of blast-driven resuspended fallout and incidental ingestion of soil and dust, which are estimated as upper bound doses (DTRA, 2010b). The upper-bound EPG doses in Table 4 are not less than the upper-bound doses potentially accrued by any member of the EPG.

Table 4. External and Internal Doses and Upper Bounds for 2MCPAEB

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	6		17	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose† (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	<0.001	0.003	0.003	0.03
Bone Surface	0.4	0.03	2	0.3
Brain	<0.001	0.002	0.003	0.02
Breast	<0.001	0.003	0.003	0.02
Stomach Wall	<0.001	0.02	0.003	0.2
Small Intestine Wall	<0.001	0.02	0.003	0.2
Upper Large Intestine Wall	<0.001	0.07	0.003	0.6
Lower Large Intestine Wall	<0.001	0.2	0.003	2
Kidney	0.002	0.003	0.007	0.02
Liver	0.08	0.005	0.4	0.04
Extrathoracic Region	0.004	0.2	0.02	2
Lung	0.008	0.4	0.04	3
Muscle	<0.001	0.002	0.003	0.02
Pancreas	<0.001	0.003	0.003	0.02
Red Marrow	0.02	0.01	0.09	0.08
Spleen	<0.001	0.003	0.003	0.02
Testes	0.005	0.001	0.03	0.009
Thymus	<0.001	0.003	0.003	0.03
Thyroid	<0.001	0.2	0.003	2
Urinary Bladder Wall	<0.001	0.005	0.003	0.05

* Initial gamma and neutron doses are treated separately and are based on the actual participant's exposure conditions at the time of detonations.

† Internal doses for this EPG include significant contributions from the inhalation of blast-driven resuspended fallout for which only upper bound values are evaluated. The contributions to EPG and upper bound EPG doses from inhalation of blast-driven resuspended fallout are numerically equal.

The upper-bound doses in Table 4 were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. The total upper-bound organ doses (combined external and internal doses) that are close to or exceed the corresponding screening dose (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 5. The total upper-bound EPG/organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40% (DTRA, 2011). In cases involving any of these organs, the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. Cancer Cases not Recommended for Expedited Processing for Operation UPSHOT-KNOTHOLE 2MCPAEB

Organ or Tissue Cancer	NTPR Standard Organ	Total Upper-Bound Organ Dose (External + Internal) (rem)
Total EPG upper-bound dose larger than the screening dose		
Liver	Liver	17
Gall bladder	Liver	17
Bile duct	Liver	17
Thyroid	Thyroid	19

6. References

Brown, W.S., 1953. "Exercise Desert Rock V Marine Corps Report," letter report to the Commandant of the Marine Corps, Headquarters 2d Marine Corps Provisional Atomic Exercise Brigade, Camp Pendleton, CA. May 19.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010a. "NuTRIS - Nuclear Test Research Information System," Defense Threat Reduction Agency, Fort Belvoir, VA.

DTRA (Defense Threat Reduction Agency), 2010b. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Frank, G., Goetz, J., Schweizer, T., Weitz, R., Klemm, J., 1982. *Analysis of Radiation Exposure for 2nd Marine Corps Provisional Atomic Exercise Brigade, Exercise Desert Rock V, Operation UPSHOT-KNOTHOLE*. DNA-TR-82-03, Defense Nuclear Agency, Washington, DC. February 5.

Kocher, D.C., Trabalka, J.R., and Apostoaei, A.I., 2009. *Derivation of Effective Resuspension Factors in Scenarios for Inhalation Exposure Involving Resuspension of Previously Deposited Fallout by Nuclear Detonations at Nevada Test Site*. DTRA-TR-09-15, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Massie, J., Maag, C., Rohrer, S., Shepanek, R., 1982. *Shot BADGER, A Test of the UPSHOT-KNOTHOLE Series, 18 April 1953.* DNA 6015F, Defense Nuclear Agency, Washington, DC. January 12.

NRC (National Research Council), 1989. *Film Badge Dosimetry in Atmospheric Nuclear Tests.* National Academy Press, Washington, DC. December.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide Revision 4*. DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

SAIC (Science Applications International Corporation), 2006. FBDOSE User's Guide, Science Applications International Corporation, McLean, VA. June 26.

VA (Department of Veteran Affairs), 2010. *Disease Subject to Presumptive Service Connection*. Electronic Code of Federal Regulations, Title 38, § 3.309. National Archives and Records Administration's Office of the Federal Register (College Park, MD) and the Government Printing Office (Washington , DC). http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl. Accessed October 18.

Weitz, R.L., Case, D.R., Chehata, M., Egbert, S.D., Mason, C.L., Singer, H.A., Martinez, D.G., McKenzie-Carter, M.A., Shaw, R.S., and Stiver, J.S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, Defense Threat Reduction Agency, Fort Belvoir, VA. November.

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Nuclear Test Personnel Review Program

Analysis of Radiation Exposure for Expedited Processing

Operation PLUMBBOB Task Force WARRIOR

November 2011

Important Note

Reconstructed doses developed for expedited processing and included in this pre-decisional document are provided for information only. The official doses for expedited processing will be published in the relevant NTPR standard operating procedure.

Expedited Processing Group: Operation PLUMBBOB Task Force WARRIOR

1. Description of the Expedited Processing Group

The Task Force WARRIOR (TFW) Expedited Processing Group (EPG) consists of approximately 350 Army personnel who were members of TFW at the Nevada Test Site (NTS) during Operation PLUMBBOB in 1957. This task force conducted the Exercise Desert Rock VII/VIII troop test at Shot SMOKY, designated as Project 50.1. TFW was a provisional unit from the 4th Infantry Division that participated in rehearsals, a maneuver exercise, and related activities at the NTS in July, August, and early September of 1957. Although not all TFW members participated in exactly the same activities, all activities that may have resulted in significant exposures to residual radiation and the sources of residual radiation resulting in exposures of TFW members were similar. That is, TFW personnel generally conducted activities typical of maneuver troops in forward NTS test areas where fallout from PLUMBBOB shots was present. Therefore, it is reasonable to include all members of TFW into a single EPG. (DTRA, 2008, Appendix C-7; Goetz et al., 1979; Harris et al., 1981).

Of the total number of personnel involved with the Project 50.1 troop test at Shot SMOKY, the primary troops composing the TFW EPG are maneuver personnel consisting of members of elements of Company C (Reinforced), 1st Battle Group, 12th Infantry listed in Table 1 (Goetz et al., 1979). Activities of other Battle Group personnel (e.g., Companies A, B, and D) are not fully documented, and may have been different than those of the personnel in elements listed in Table 1.

Table 1. Elements of Company C, 1st Battle Group, 12th Infantry included in TFW

Element	Size
Company Headquarters	12
Four rifle platoons (1st, 2nd, 3rd, and 4th Platoons)	188
Weapons Platoon	36
Reconnaissance Platoon	21
1st Platoon, Mortar Battery	54
Medical Detachment	17
Communications Detachment	16
3rd Squad, Engineer Platoon	7

Project 50.1 personnel may be included in expedited processing under this EPG only if the extent of their participation is encompassed by the activities described herein for the TFW EPG analysis. The following individuals and units who were members of or affiliated with TFW are excluded from expedited processing under this EPG:

- Members of the 7th Platoon, Queen's Own Rifles (a Canadian Army Platoon).
- Members of the 3rd Transportation Battalion (Helicopter).
- Any 1st Battle Group personnel who are not in one of the units identified in Table 1 and whose activities are not encompassed by the TFW activities described herein.

2. Basis of Dose Analysis for Task Force WARRIOR

To estimate bounding doses for all TFW members, an exposure scenario was developed based on activities of the cohort group that received the highest dose from exposure to external residual radiation and corresponding internal doses. This cohort is referred to as the "highest-dose cohort." Exposures to initial neutron and gamma radiations are not taken into consideration when selecting a "highest-dose cohort" because these sources are not correlated to the scenario of exposure beyond the first minute after a shot and are not associated with accrual of internal doses.

Complete and reliable film badge records are available for TFW personnel and were used in the TFW EPG analysis. These records were used first to identify the highest-dose cohort. The film badge records were subsequently used to estimate the dose for TFW activities in an area of the test site where no survey data are available and where the highest exposures of TFW occurred. For two film badge periods together encompassing the time from July 25 to September 2, 1957, there is a group of 20 badges with an average total reading about 1 rem higher than the average for all other badges. The mean of the total film badge readings of the group of 20 badges is 1.545 rem (upper bound is 2.128 rem), whereas the mean of the total film badge readings for all other badges is 0.575 rem (upper bound is 0.789 rem) (Goetz et al., 1979; NRC, 1989; SAIC, 2006). About 0.14 rem of these mean readings is due to initial DOPPLER gamma radiation (Goetz, et al., 1979). The difference in film badge readings noted above is primarily due to the film badges worn during the period of August 27–September 2 that encompasses the date of Shot SMOKY on August 31. The film badge readings for this period account for 0.955 rem out of the total difference of 0.970 rem in mean readings. Based on the readings and the film density characteristics of the 20 badges worn on August 31, it was concluded (Goetz et al., 1979) that the personnel wearing them were together when their badges were exposed. Furthermore, based on the possible sources of exposure on August 31, these badges were worn by a platoon section, patrol, or task group that was exposed to higher levels of SMOKY fallout than other members of TFW, likely during the assault on Quartzite Ridge east of the primary objective area. Accordingly, the activities of this group of 20 TFW personnel form the basis for the generic highest-dose cohort. For the purpose of developing an exposure scenario, these badges are assumed to have been worn by members of the 2nd Platoon, which is identified as the highest-dose cohort because this platoon participated in the assault on Quartzite Ridge and also because it was in the first serial transported to the primary objective on SMOKY shot day.

Reliable radiation survey data are available for the majority of TFW activities, and these survey data were used to reconstruct doses for most activities of this EPG. However, survey data are not available for the area of the assault on Quartzite Ridge. Therefore, film badge records were used to estimate the 2nd Platoon dose from exposures during the assault.

For use with the EPG, the generic highest-dose cohort scenario is augmented with additional exposure pathways, reasonably maximizing assumptions, and high-sided values for some dose calculation parameters. This ensures that the results bound the doses for all members of the EPG. The members of the 2nd Platoon, TFW, form an adequate basis of the generic highest-dose cohort scenario for this EPG for the following primary reasons (DTRA, 2008, Appendix C-7; Goetz et al., 1979):

- The average external gamma dose from residual radiation for members of the 2nd Platoon was the largest dose for any TFW participant groups.
- The 2nd Platoon formed a cohesive unit during the period of their greatest exposure.
- With the exception of one additional exposure from inhalation of descending SMOKY fallout, the sources of radiation exposure for the 2nd Platoon are similar to those of other TFW personnel.

As explained below, several dose components and assumptions were added to the documented 2nd Platoon scenario to produce EPG doses. The basic scenario is described directly below, followed by a description of the additional maximizing assumptions.

3. Highest-Dose Cohort Scenario: 2nd Platoon of TFW

To estimate bounding doses for all military personnel assigned to TFW during Operation PLUMBBOB, a generic high-sided exposure scenario was developed based on activities of the 2nd Platoon. Most 2nd Platoon members arrived at CDR in late July 1957 and stayed until after the completion of their exercise in early September 1957. Activities of the 2nd Platoon in forward NTS areas included four rehearsals conducted August 5–8; preparation of defensive positions on August 12–13; observation of Shot DOPPLER on August 23; and observation of Shot SMOKY and participation in a maneuver on August 31, including an assault on Quartzite Ridge. Some members of the 2nd Platoon may have also been assigned to the teams that recovered equipment in the maneuver area and inspected the defensive positions following the maneuver. (DTRA, 2008, Appendix C-7; Goetz et al., 1979)

Sources of external exposure routinely included for the 2nd Platoon consist of residual fallout from several shots during TFW rehearsals, preparation of defensive positions, maneuver activities, and while billeted at CDR. As described below, additional external exposures from residual fallout during equipment recovery and inspection of defensive positions are also included for this EPG analysis, as is exposure to descending SMOKY fallout during the assault on Quartzite Ridge. Unlike for most TFW activities, reliable survey data are not available for the area of the assault on Quartzite Ridge. Therefore, it was assumed that the difference of 0.955 rem between mean film badge readings for the second badged period described above was accrued during the assault. In addition, based on an evaluation of TFW exposures (NRC, 2003), it is assumed that the dose increment of 0.955 rem is attributable to SMOKY fallout descending from a portion of the rising SMOKY fireball that was transported to the area of the assault on Quartzite Ridge. To implement this assumption, a descending SMOKY fallout exposure rate function and exposure period were defined such that the calculated film badge equivalent external dose for the period of the assault on Quartzite Ridge equaled the film badge increment of 0.955 rem.

Average fallout exposure rates associated with 2nd Platoon activities are shown in Table 2. The highest exposure rates encountered by the 2nd Platoon were those encountered during the activities conducted on SMOKY shot day (August 31), as shown in Figure 1. The constant exposure rate shown in Figure 1 for the period H−2 to H+1.5 corresponds to the time spent at the location from where they observed Shot SMOKY (primarily due to KEPLER fallout, see Table 2). The 2nd Platoon then moved to Helicopter Loading Area B, where they experienced a slightly lower exposure rate (also from KEPLER) for a short time until they loaded into helicopters and were transported to the Primary Objective Area. At this location they were exposed to a relatively constant exposure rate (primarily from SHASTA fallout) during the period H+1.75 to H+3, which corresponds to the time spent at the Primary Objective prior to the assault on Quartzite Ridge. The increasing exposure rate for the period approximately H+3 to H+4.25 corresponds to the time of the assault. The assault exposure rates were derived using the increment of higher film badge reading for this cohort as described above, assuming that the source was descending SMOKY fallout. A simple descending fallout function was developed that involved fallout descending between H+1 and H+6 with a peak intensity of 2.1 R hr^{-1} at H+6. Therefore, the 2nd Platoon is assumed to have experienced descending SMOKY fallout during roughly the middle third of its assumed period of deposition at the Quartzite Ridge assault location; the highest estimated exposure rate experienced by the 2nd Platoon is about 1.4 R hr^{-1}. As reflected in Figure 1, after the conclusion of the assault at H+4.25, the 2nd Platoon returned to the Primary Objective Area, and then was transported to CDR by H+5.5.

Sources of internal exposure include inhalation of resuspended fallout during TFW rehearsals, preparation and post-shot inspection of defensive positions, maneuver activities, equipment recovery activities, and while at CDR, and incidental ingestion of contaminated soil and dust at CDR. Activities resulting in resuspension of fallout included proximity to helicopter operations, SMOKY blast effects, hand-digging defensive positions, and typical activities such as walking over open terrain. In addition to resuspended fallout and incidental ingestion, members of 2nd Platoon are assumed to have inhaled descending SMOKY fallout during the assault on Quartzite Ridge (DTRA, 2008, Appendix C-7; Goetz et al., 1979; NRC, 2003).

Table 2. Activities and Fallout Exposure Rates Relevant to the 2nd Platoon of TFW

Date(s) of Activity (1957)	Activity and Locations	Source of Fallout (Shot)	Exposure Rate* ($R\ hr^{-1}$)
August 5 and August 6	Rehearsals Observation Area/Loading Area B	WILSON KEPLER	0.00006 0.005
August 7 and August 8	Observation Area/Loading Area A	BOLTZMANN FRANKLIN WILSON	0.00004 0.000004 0.00003
August 5 and August 7	Primary Objective	BOLTZMANN DIABLO	0.00004 0.001
August 6 and August 8	Secondary Objective	DIABLO	0.003
August 12–13	Preparation of Defensive Positions Defensive Positions Area	BOLTZMANN DIABLO	0.0012 0.029
August 31	Observation of SMOKY Observation Area/Loading Area B	WILSON KEPLER	0.000003 0.008
August 31	TFW Maneuver Loading Area B	WILSON KEPLER	0.00006 0.005
	Primary Objective Area	BOLTZMANN DIABLO SHASTA	0.0003 0.00005 0.04
	South of Quartzite Ridge	SMOKY	2.1†
August 31	SMOKY Shot Area (used only for internal dose calculations)	BOLTZMANN DIABLO SHASTA	0.0003 0.005 0.01
September 1	Equipment Recovery Primary Objective Area	BOLTZMANN DIABLO SHASTA	0.0003 0.00005 0.028
September 1	Inspection of Defensive Positions Defensive Positions Area	BOLTZMANN DIABLO SHASTA SMOKY	0.0009 0.016 0.02 0.025
July 15–Nov 22	CDR	WILSON	0.0004‡

* Most exposure rates listed are average values experienced by TFW for the date(s) of each activity/location, estimated from survey data (Goetz et al., 1979). Exceptions are noted.

† This exposure rate from SMOKY fallout south of Quartzite Ridge is the peak exposure rate on August 31 in this area, estimated using film badge readings; it is estimated to have occurred at H+6 (see text for details of this estimate).

‡ This is the peak exposure rate from WILSON fallout measured at CDR (DTRA, 2008, Appendix C-7).

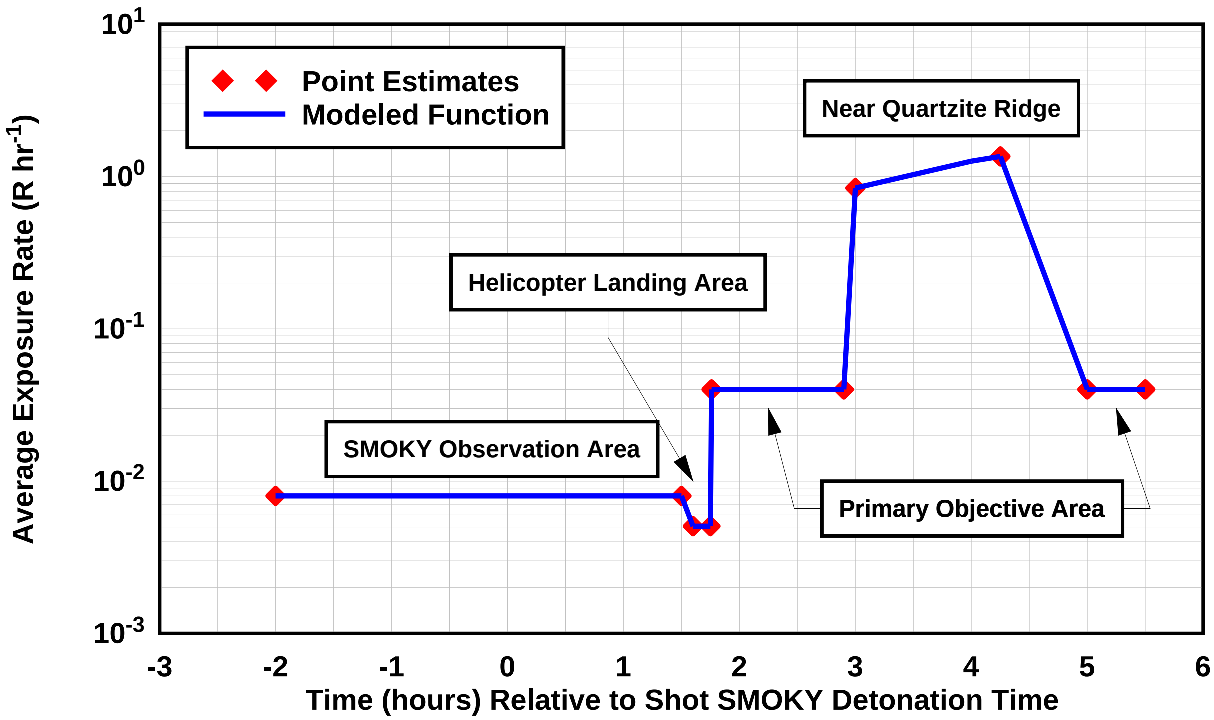

Figure 1. Fallout Exposure Rates Encountered by 2nd Platoon on SMOKY Shot Day

4. Maximizing Scenario and Parameter Assumptions

The following additional dose components and assumptions were added to or substituted into the 2nd Platoon of TFW scenario cohort analysis.

- The normal period of assignment at CDR for TFW personnel was approximately 40 days, from late July until early September, 1957. In order to reasonably maximize the exposure of TFW personnel to WILSON fallout at CDR, the period of assignment for the EPG analysis was increased to 130 days by assuming an arrival date of July 15, 1957 (after the last departure date of Marine personnel participating at Shot HOOD), and lasting until November 22, 1957 (one month after the end of PLUMBBOB) (Harris et al., 1981; Maag et al., 1983; VA, 2010).
- On September 1, a recovery party consisting of about 15 TFW personnel was transported to the Primary Objective area. It was assumed that a member of the 2nd Platoon was assigned to this recovery party, which was transported by helicopter to the Primary Objective area to recover equipment and supplies left there on shot day. These personnel spent about 2 hours in the Primary Objective area locating and collecting equipment (Goetz et al., 1979).
- On September 1, selected TFW personnel inspected the defensive positions to determine the effects of the SMOKY detonation on the previous day. It was assumed for the EPG analysis that a member of the 2nd Platoon was included in this activity. The inspection team was transported to the area of the defensive positions by helicopter, and spent about 2 hours inspecting and recording the damage before returning to CDR.

- The number of hours spent outdoors at CDR by TFW personnel was increased from the CDR default of 14.4 to 16 hr day^{-1}, while 8 hours each day were spent in a tent while sleeping, cleaning and eating.
- Rather than using an exposure rate decay model based on the default decay term of (H+hours)$^{-1.2}$, the time-dependent decay of WILSON fallout at CDR was modeled using a series of decay exponents other than (−1.2) that represent the composite decay of a generic PLUMBBOB shot (Table II-5, Goetz et al., 1979). This results in higher exposure rates than those obtained from use of the default decay term, and results in a 30 percent higher external dose for the period of TFW exposure to WILSON fallout at CDR.
- Exposure rates used for DIABLO fallout at the defensive positions and SHASTA fallout at the Primary Objective Area reflect increases of 30 percent and 20 percent, respectively, over average values in those areas. This accounts for the possibility that the members of the highest-dose cohort may have conducted their activities close to the line of highest exposure rate along the fallout path of these shots (Goetz et al., 1979).
- Inhalation of respirable descending SMOKY fallout during the assault on Quartzite Ridge was included as a maximizing internal dose pathway for 2nd Platoon troops. This dose pathway is based on the assumption of a northwesterly wind at low elevations that transported lower portions of the SMOKY nuclear cloud to the area of the assault, and has been described to explain the additional external dose received by the highest-dose cohort (NRC, 2003). Note that the assumption that all of the fallout particles were respirable constitutes the maximizing feature of this assumption because fallout at H+3 to H+4 would likely contain a large fraction of particles that would be too large to be respired (Glasstone and Dolan, 1977).
- Exposure to blast-driven resuspended fallout during the assault on Quartzite Ridge was included as a maximizing dose pathway for 2nd Platoon troops, although the area of the assault was outside the area of blast-driven resuspension (Kocher et al., 2009). This dose pathway was included based on the same assumption of a northwesterly wind at low elevations that was made as the basis for the inclusion of the descending fallout dose pathway. As a conservative assumption, blast-driven resuspended fallout from PLUMBBOB shots BOLTZMANN, DIABLO, and SHASTA was assumed to be resuspended by effects of the SMOKY detonation and transported without dilution to the Quartzite Ridge assault area.
- The breathing rate for outdoor activities was increased from the default value of 1.2 to 2.0 m^3 hr^{-1}. The higher value is based on the assumption of personnel activities consisting of a mix of 50 percent light activity and 50 percent moderate activity (Weitz et al., 2009). Other combinations of activity levels, including short durations of both rest and heavy activity levels, result in a similar average outdoor breathing rate.

Exposure pathways for the EPG scenario are described in Table 3. Values used for the primary parameters in the EPG external and internal dose analyses are shown in Table 4.

Table 3. Exposure Pathways for TFW Troops

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factors
EXTERNAL		
Radiation from residual and descending fallout at locations in the forward area	Members of 2nd Platoon were exposed to fallout from seven shots during rehearsals, preparation of defensive positions, and maneuver activities. A limited number of TFW personnel were also exposed during recovery of equipment and inspection of defensive positions.	Exposure rates for DIABLO fallout at the defensive positions and SHASTA fallout at the Primary Objective are higher than average rates by 30 percent and 20 percent respectively.
Residual radiation from fallout at billet location	Members of 2nd Platoon were exposed to WILSON fallout at CDR from late July until early September.	Assignment at CDR is approximately 130 days instead of 40 days. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}. WILSON fallout exposure rate decay model is based on composite PLUMBBOB decay terms instead of on the default decay model, resulting in a 30 percent higher external dose for this pathway.
INTERNAL		
Inhalation of resuspended fallout during forward-area activities	Members of 2nd Platoon inhaled resuspended fallout during rehearsals, preparation of defensive positions, and the maneuver. A limited number of TWF personnel inhaled resuspended fallout while participating in post-shot equipment recovery and inspection of defensive positions after SMOKY shot day.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of descending fallout	Members of 2nd Platoon inhaled respirable-sized descending SMOKY fallout on August 31 during the assault on Quartzite Ridge from H+3 until H+4.25.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of blast-driven resuspended fallout	Members of 2nd Platoon inhaled blast-driven resuspended fallout from previous PLUMBBOB shots during the assault on Quartzite Ridge.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of fallout resuspended by helicopter operations	Members of 2nd Platoon inhaled resuspended fallout due to helicopter rotor wash during loading/unloading conducted during rehearsals, preparation of defensive positions, and the maneuver. Some TWF personnel inhaled rotor wash-resuspended fallout during equipment recovery and inspection of defensive positions.	Breathing rate is 2 m^3 hr^{-1} instead of 1.2 m^3 hr^{-1}.
Inhalation of resuspended fallout at billet location	Members of 2nd Platoon inhaled resuspended WILSON fallout while outdoors at CDR from late July until early September.	Assignment at CDR is approximately 130 days instead of 40 days. Breathing rate is 2 m^3 hr–^{1} instead of 1.2 m^3 hr^{-1}. Number of hours outside is 16 hr day^{-1} instead of 14.4 hr day^{-1}.
Incidental ingestion of contaminated soil/dust at billet location	Members of 2nd Platoon incidentally ingested soil and dust at CDR contaminated from WILSON fallout from late July until early September.	Assignment at CDR is approximately 130 days instead of 40 days.

Table 4. Input Parameter Values for the Calculation of EPG Doses

Parameter	Definition	Value
DATES AND TIMES		
$Date_{ArrCDR}$	Date [time] of arrival at CDR	15 July 57[0800]
$Date_{DepCDR}$	Date [time] of departure from CDR (1 month after the end of PLUMBBOB)	22 Nov 57[1200]
Duration	Duration of TFW activities at specific locations (Goetz et al., 1979)	
	Each Rehearsal: Helicopter Loading/Observation Areas Primary Objective Area Secondary Objective Area	 2 hr 4 hr 2 hr
	Preparing defensive positions Digging Traveling to/from area Inspection	 7.5 hr 2 hr 2.5hr
	Maneuver: Observation Area Helicopter Loading Area Objective Area Assault on Quartzite Ridge	 3.5 hr 0.25 hr 2.5 hr (= 1.25 + 1.25) 1.25 hr
	Equipment Recovery (Objective Area)	2 hr
	Inspecting defensive positions after SMOKY	2 hr
EXTERNAL DOSE		
Intshot	Average or peak fallout exposure rates at each location during TFW activities	See Table 2
Int_{SMQz}	SMOKY fallout exposure rates near Quartzite Ridge (Note: 2nd Platoon was present at this location from H+3 to H+4.25).	0.21 R hr^{-1} @ H+1 0.42 R hr^{-1} @ H+2 0.84 R hr^{-1} @ H+3 1.3 R hr^{-1} @ H+4 1.7 R hr^{-1} @ H+5 2.1 R hr^{-1} @ H+6 (peak)
Int_{WL}	Average WILSON fallout exposure rates at CDR	0.0001 R hr^{-1} @ H+3.8 0.0004 R hr^{-1} @ H+12.9 (peak)
λ	Default fallout exposure rate decay exponent for times less than 6 months after shot (used as [H+hours]$^{\lambda}$)	−1.2
	Fallout exposure rate decay model for shots FRANKLIN, WILSON, KEPLER	PLUMBBOB composite decay rates (Tables II-5 and II-6, Goetz et al., 1979)
	Fallout exposure rate decay models for shots BOLTZMANN, DIABLO, SHASTA, and SMOKY	Shot-specific decay rates based on measured exposure rates (Tables II-1 to II-4 and II-6, Goetz et al., 1979)
F_{os}	Fraction of time spent outside at CDR	0.67 (= 16/24)
F_{tent}	Fraction of indoor time at CDR spent in a tent	1.0
PF_t	Protection factor while inside a tent	1.5 (DTRA, 2008)
TWSF	Time-Weighted Shielding Factor for time at CDR (calculated using F_{os}, F_{tent}, and PF_t)	0.889

Table 4. Input Parameter Values for the Calculation of EPG Doses (cont.)

Parameter	Definition	Value
EXTERNAL DOSE		
F_B	Film badge equivalent conversion factor	0.7 rem R^{-1} (DTRA, 2010, SM ED02)
UF_{ext}	Upper bound factor for external doses	3 (DTRA, 2010, SM UA01)
INTERNAL DOSE		
BR	Breathing rate for activities in outside areas	2.0 m^3 hr^{-1}
$K(t)$	Time-dependent resuspension factor	$K(t) = 10^{-5} \times \exp(-0.01 \times t/24) + 10^{-9}$ m^{-1} (DTRA, 2010, SM ID01)
K_{dig}	Resuspension factor used for digging of defensive positions	10^{-4} m^{-1} (DTRA, 2010, SM ID01)
K_{helo}	Resuspension factor for helicopter operations	10^{-3} m^{-1} (DTRA, 2010, SM ID01)
K_{blast}	Resuspension factor for blast-driven resuspension	$(10^{-3}\ m^{-1} \times 10^{-4}\ m^{-1})^{0.5} = 3.16 \times 10^{-4}\ m^{-1}$ (DTRA, 2010, SM ID01)
Dur_{dig}	Duration of enhanced resuspension during digging while preparing defensive positions	7.5 hr
Dur_{helo}	Duration of each exposure to highly-resuspended fallout in the vicinity of helicopter operations	3 min
Num_{helo}	Total number of exposures to highly-resuspended fallout while loading and unloading from helicopters	24
Duration	Duration of inhalation of descending SMOKY fallout and blast-driven resuspended fallout in the vicinity of the assault on Quartzite Ridge	1.25 hr
F_{os}	Fraction of time spent outside at CDR	0.67 (= 16/24)
q_{ing}	Soil incidental ingestion rate	500 mg day^{-1} (DTRA, 2010, SM ID01)
ρ_{soil}	Soil bulk density (for incidental soil ingestion pathway)	1.3 g cm^{-3} (DTRA, 2010, SM ID01)
Thick	Thickness of contaminated soil layer (for incidental soil ingestion pathway)	0.01 m (DTRA, 2010, SM ID01
DCF_{Inh} DCF_{Ing}	Fallout inhalation and ingestion dose conversion factors	per FIIDOS (selected maximum values among particle sizes of 1–10 µm for inhalation) (Raine et al., 2007; DTRA, 2010, SM ID01)
RhrCim2	Fallout radiation exposure rate/surface activity ratios	per FIIDOS (Raine et al., 2007; DTRA, 2010, SM ID01)
UF_{int}	Upper bound factor for internal doses	10 (DTRA, 2010, SM UA01)

5. Summary of EPG Doses and Upper Bounds

The EPG external and internal doses and corresponding upper-bound doses for the TFW Troops EPG are summarized in Table 5. The upper-bound external gamma dose from residual radiation is calculated by applying an uncertainty factor of 3 to independent components of the EPG dose. However, for expedited processing doses, all external dose components are assumed to be correlated as a conservative assumption. This is equivalent to estimating upper bound external doses by multiplying the total external dose by an uncertainty factor of 3. The upper bound internal doses are calculated by multiplying the EPG internal doses by a factor of 10, except for doses from incidental ingestion of soil and dust, and doses from inhalation of blast-driven resuspended fallout inhalation, which are estimated as upper bound doses (DTRA, 2010). The upper-bound EPG doses in Table 5 are not less than the upper-bound doses potentially accrued by any member of the EPG.

The EPG and upper-bound EPG external doses in exceed the mean and upper-bound film badge readings of 1.545 rem and 2.128 rem discussed above. In addition, excluding outliers with questionable readings, the highest possible combined TFW film badge dose for the two film badge periods described above is no more than 2 rem, with a corresponding upper bound of no more than 2.8 rem (Goetz et al., 1979; NRC, 1989; SAIC, 2006). Therefore, the upper-bound EPG external dose in exceeds the highest upper-bound TFW dose based on film badge readings.

The upper-bound doses in were calculated using a highest-dose cohort scenario and were further increased by the use of additional high-sided assumptions. However, the upper-bound EPG doses do not include contributions from initial radiation, which must be considered for cases involving certain organs before processing these cases using expedited processing. Members of this EPG received neutron and initial gamma doses while observing Shot DOPPLER; the upper-bound neutron dose is 1.7 rem, and the upper-bound gamma dose is 0.42 rem (Goetz et al., 1979; Weitz and Egbert, 2010).

To assess the impacts of initial doses on expedited processing decisions for members of this EPG, total upper-bound organ doses (combined upper-bounds for EPG external, EPG internal, and initial doses) were calculated for all organs. The resulting total upper-bound organ doses that are close to or exceed corresponding screening doses (DTRA, 2011) for the specific organ or tissue cancer for members of this EPG are listed in Table 6. The total upper-bound organ dose is deemed close to the screening dose for the corresponding cancer model if the estimated probability of causation is equal to or higher than 40 percent (DTRA, 2011). Because of the potential for initial doses for members of this EPG, in cases involving any of the organs listed in Table 6 the EPG upper-bound doses may not be appropriate for assignment to all members of the EPG by means of expedited processing as discussed in DTRA (2011).

Table 5. External and Internal Doses and Upper Bounds for Task Force Warrior

External Doses	EPG Dose (rem)		Upper-Bound EPG Dose (rem)	
Residual Gamma Radiation	2		5	
Initial Gamma*	-		-	
Neutron*	-		-	
Internal Doses for NTPR Standard Organs	**EPG Dose (rem)**		**Upper-Bound EPG Dose (rem)**	
	Alpha	**Beta + Gamma**	**Alpha**	**Beta + Gamma**
Adrenals	0.003	0.01	0.02	0.09
Bone Surface	2	0.3	10	2
Brain	0.003	0.006	0.02	0.06
Breast	0.003	0.009	0.02	0.07
Stomach Wall	0.003	0.08	0.02	0.7
Small Intestine Wall	0.003	0.1	0.02	1
Upper Large Intestine Wall	0.003	0.3	0.02	3
Lower Large Intestine Wall	0.003	0.5	0.02	4
Kidney	0.006	0.009	0.05	0.08
Liver	0.3	0.06	2	0.4
Extrathoracic Region	0.02	0.9	0.2	9
Lung	0.05	0.9	0.4	8
Muscle	0.003	0.009	0.02	0.08
Pancreas	0.003	0.01	0.02	0.09
Red Marrow	0.06	0.04	0.5	0.4
Spleen	0.003	0.009	0.02	0.08
Testes	0.02	0.007	0.2	0.06
Thymus	0.003	0.02	0.02	0.1
Thyroid	0.003	0.9	0.02	9
Urinary Bladder Wall	0.003	0.03	0.02	0.3

* Initial gamma and neutron doses are treated separately and are based on the actual participant's exposure conditions at the time of detonations.

Table 6. Cancer Cases not Recommended for Expedited Processing for Task Force WARRIOR

Organ or Tissue Cancer	NTPR Standard Organs	Total Upper-Bound Organ Dose (External + Internal + Initial) (rem)
Total upper-bound dose larger than the screening dose		
Thyroid	Thyroid	16
Total upper-bound dose below but close to the screening dose		
Liver	Liver	9.5

6. References

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a*. DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2011. *Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency, Fort Belvoir, VA.

Glasstone, S. and Dolan, P.J., 1977. *The Effects of Nuclear Weapons*. Third Edition. U.S. Department of Defense and U.S. Department of Energy.

Goetz, J. L., Kaul, D., Klemm, J., and McGahan, J.T., 1979. *Analysis of Radiation Exposure For Task Force WARRIOR–Shot SMOKY–Exercise Desert Rock VII – VIII, Operation PLUMBBOB*. DNA 4747F, Defense Nuclear Agency, Washington, DC. May 31.

Harris, P.S., Lowery, C., Nelson, A.G., Obermiller, S., Ozeroff, W.J., and Weary, E., 1981. *Shot SMOKY, A Test of the PLUMBBOB Series,* DNA 6004F, Defense Nuclear Agency, Washington, DC. May 31.

Kocher, D.K., Trabalka, J.R., and Apostoaei, A.I., 2009. *Derivation of Effective Resuspension Factors in Scenarios for Inhalation Exposure Involving Resuspension of Previously Deposited Fallout by Nuclear Detonations at Nevada Test Site*. DTRA-TR-09-15, Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

Maag, C., Wilkinson, M., Striegel, J., and Collins, B., 1983. *Shot HOOD, A Test of the PLUMBBOB Series*. DNA 6002F, Defense Nuclear Agency, Washington, DC. May 13.

NRC (National Research Council), 1989. *Film Badge Dosimetry in Atmospheric Nuclear Tests*. National Academy Press, Washington, DC. December.

NRC (National Research Council), 2003. *A Review of the Dose Reconstruction Program of the Defense Threat Reduction Agency.* The National Academies Press, Washington, DC.

Raine, D.A. III, Egbert, S.D., Stiver, J.H., and Case, D.R., 2007. *FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide, Revision 4.* DTRA-TR-07-11, Defense Threat Reduction Agency, Fort Belvoir, VA. May.

SAIC (Science Applications International Corporation), 2006. FBDOSE User's Guide, Science Applications International Corporation, McLean, VA. June 26.

VA (Department of Veterans Affairs), 2010. "Disease subject to presumptive service connection". Title 38, Part 3.309, Electronic Code of Federal Regulations. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl. Accessed October 18.

Weitz, R. L., Case, D. R., Chehata, M., Egbert, S. D., Mason, C. L., Singer, H. A., Martinez, D. G., McKenzie-Carter, M. A., Shaw, R. S., and Stiver, J. S., 2009. *A Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments*. DTRA-TR-09-13, and Defense Threat Reduction Agency, Fort Belvoir, VA. November.

Weitz, R. L., and Egbert, S. D., 2010. *Compilation of Initial Radiation Doses to Atmospheric Test Participants (Revision 1)*. NTPR-TM-09-01 (R1). Defense Threat Reduction Agency, Fort Belvoir, VA. November 30.

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