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TECHNICAL REPORT

A Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments

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14. ABSTRACT
This report describes the technical bases of an updated methodology that can be used in expedited processing of radiation dose assessments (RDA) for the Nuclear Test Personnel Review (NTPR) Program. The report defines the approach employed for selecting expedited processing groups (EPG), discusses the technical methods and assumptions used for estimating “maximized doses” and upper bound doses for each EPG, and summarizes the results of the dose assessment analyses. The detailed descriptions of each proposed EPG and its associated doses are contained in a separate volume—The Compendium of Expedited Processing Groups (DTRA-TR-11-01). The evaluation of the currently-used methods and technical basis of NTPR expedited processing of RDAs is documented in an interim report—Development of Radiation Doses to Support Expedited Processing of NTPR Dose Assessments, Pilot Phase Interim Report (NTPR-TM-10-03).

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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.

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1.

Introduction

This technical basis document describes the methods and approaches that were developed to support the expedited processing of some radiation dose assessments (RDAs) for Nuclear Test Personnel Review (NTPR) Program participants. It supports the Defense Threat Reduction Agency's (DTRA's) implementation of a recommendation of the Veterans' Advisory Board on Dose Reconstruction (VBDR) that "NTPR expand its technical bases and criteria for expedited case processing…" (VBDR, 2007c).

The proposed approach to estimating equivalent doses for use in expedited processing of RDA cases involves evaluations for expedited processing groups (EPGs), which comprise large numbers of individuals with similar exposure circumstances and radiation environments. The goal of this approach is to calculate EPG doses, whose upper bounds at the 95th percentile are demonstrably higher than the dose that any individual in the group could have received. The upper-bound doses are compared with cancer screening doses that likely would result in a Department of Veterans Affairs (VA) service-connected disability determination. If the EPG doses are well below the screening doses, no further refinement for accuracy is needed, and the EPG doses can be reported to the VA. This approach provides for the timely and cost-effective completion of RDAs to which it applies while giving full benefit of the doubt to claimants whose cases are being adjudicated by the VA.

It is important to note that the assumptions made in calculating the EPG doses are even more conservative (i.e., they result in higher estimated doses) than the already high-sided assumptions documented in the NTPR Standard Operating Procedures (SOP) Manual and Standard Methods (SMs) for performing individual-specific, full RDAs (DTRA, 2008; DTRA, 2010a). In some instances, assumed input parameters meant to further increase the dose for the EPG would be impossible under the conditions that an individual veteran in the EPG actually experienced. For example, it is generally assumed that members of an EPG remained in the test area throughout a specified period of time; however a specific member of an EPG might have departed the test area early and therefore missed a major fallout event experienced by other members of the EPG. Nevertheless, he is given the same EPG dose that he would receive if he had been continuously present at the test site. Because of the inherent high-sidedness of EPG doses, expedited processing allows DTRA to provide more timely RDA results for the VA and ultimately for the veteran for cases in which doses are likely well below the level that would result in service-connected disability determinations.

This report reviews the current state of NTPR's expedited processing of RDA cases, describes the methods for defining EPGs, discusses the technical methods and assumptions for estimating "maximized doses" for the EPGs, and summarizes the results of initial analyses. Detailed descriptions of each proposed EPG and its associated doses are contained in a separate volume—

The Compendium of Expedited Processing Groups (DTRA, 2011), hereinafter called the EPG Compendium.

1.1 Background

In 2005, DTRA faced a backlog of almost 2,000 VA claims that required dose reconstructions and would have involved several years of effort at substantial cost to address with individual RDAs. Between January 2006 and December 2008, in response to VDBR recommendations, DTRA implemented expedited processing, first for cases involving skin cancer, prostate cancer, and posterior subcapsular cataracts; and subsequently for most other cancer cases when scientifically justified (Blake, 2009). This section presents the rationale for expediting RDA cases, reviews the historical development of the current process, discusses the criteria for expediting cases, and summarizes benefit-of-the-doubt considerations.

1.1.1 Rationale for Expediting Radiation Dose Assessment Case

DTRA requires efficient methods for estimating radiation dose to participants in the U.S. atmospheric nuclear test program as well as personnel who were present in Japan at the end of World War II and the following occupation period. One approach to achieve this efficiency is to assign doses that are larger than the maximum dose the participants of a well-defined EPG could have received, based on the circumstances of their exposure scenarios. If such conservatively-estimated doses are known to be well below the dose that could result in a service-connected disability determination, VA could then make a determination with the confidence that claimants had received the full benefit of the doubt in determining their doses.

Given a reconstructed dose to an organ with cancer (e.g. dose to the liver in cases involving liver cancer), an evaluation can be made of the likelihood that this dose caused the cancer. Service-connected determinations about whether a cancer is at least as likely as not associated with the given dose are based upon whether a probability of causation (PC) derived for that dose—determined at the upper 99th percentile, taking into account uncertainties in estimated risk—is equal to or greater than 50 percent. These evaluations of likelihood can have three possible outcomes: 1) the dose is well below the dose required to produce a PC of 50 percent, 2) the dose is well above the dose required to produce a PC of 50 percent, or 3) the dose is close to the dose required to produce a PC of 50 percent.

1.1.2 History of Current Process

In late 2005, DTRA faced an enormous backlog of RDA cases with some case processing times approaching 4 years. Costs per case were also increasing, due to 1) the complex analyses and case-specific documentation of its "DTRA Dose Reconstruction Policy" in *Title 32, Code of Federal Regulations, Part 218* (32 CFR 218) released in 1985, and 2) increased veteran or claimant involvement in providing and reviewing the full details of exposure scenarios as

recommended in the 2003 review of DTRA's dose reconstruction program by a Committee of the National Research Council of the National Academies of Science (NAS/NRC, 2003). Increased dose reconstruction resources failed to affect backlogs significantly. Consequently, DTRA considered two possible courses of action (Blake, 2009):

- Revise 32 CFR 218—a challenging, time-consuming effort during a period of claims-processing delays and veteran frustration.
- Obtain veteran buy-in to proposed changes through a VBDR recommendation to DTRA and/or VA.

In January 2006, DTRA briefed the VBDR on a technical justification for an expedited approach to re-working RDA cases involving cancer of the prostate. DTRA subsequently released a point paper for public distribution and a restricted release technical basis document to the Subcommittee on DTRA Dose Reconstruction Procedures (SC-1) of the VBDR. These actions led to several VBDR recommendations for expedited processing, including:

- July 2006 recommendations to expedite prostate cancer and skin cancer cases (VBDR, 2006).
  - Implementation followed a review of substantial numbers of prostate cancer cases that showed a low upper-bound external dose, as well as a review of cases involving skin cancer that showed large uncertainties resulting in very high upper-bound doses to the skin.
- March 2007 recommendation to develop an expedited process for posterior subcapsular cataracts (VBDR, 2007a).
  - Implementation followed reviews showing large uncertainties in estimating dose to the eye lens and very high upper-bound doses; the results were similar to the situation observed in skin cancer cases.
- May 2007 recommendation to develop an expedited dose process for most other cancers, where scientifically justified (VBDR, 2007b).
  - Implementation followed review of a large number of cases that produced estimated doses from exposures to external and internal radiation sources, some of which were above and some of which were below the doses expected to result in a successful claim.

Implementation of these "expedited process" recommendations allowed DTRA to reduce the substantial case backlog and improve case processing time. Following implementation of these recommendations, an increase from 9 to 29 percent was observed in VA service-connected medical opinions for NTPR "expedited processing" cases, particularly for skin cancer and cataract cases. (Blake, 2009)

Finally, VBDR recommended that DTRA "expand its technical bases for expedited processing" (VBDR, 2007c). To address this final recommendation, DTRA's NTPR Program evaluated historical dose reconstruction cases, developed approaches to cost-effective methods for estimating doses in expedited processing, and produced this technical basis document on the

expedited approach to NTPR RDAs for cases involving organs and tissues other than those for skin and prostate cancers and posterior subcapsular cataracts, which are currently processed using approaches with an acknowledged technical basis. This technical basis document describes the methods that have been developed to expand the technical basis for expedited dose reconstruction cases of most other cancers, and are recommended for future implementation.

1.1.3 Decision Criteria for Expediting Dose Assessment Cases

In its recommendations to expand expedited processing to cases involving most other cancers, "where scientifically justified, and for which the doses are either well above or well below the level likely to result in a successful claim…[1]" VBDR (2007b) discussed features to be considered in developing the procedures for determining doses. These considerations include:

- The expedited upper-bound (UB) dose estimates would be used by "VA in evaluating whether it is at least as likely as not, with 99 % confidence that the veteran's cancer was caused by service-related radiation, while assuring the veteran receives full benefit of the doubt."
- The doses should be upper bounds based on dose reconstructions that are "more broadly generated and applied than those in previous single-case dose reconstructions."
- The doses will "almost always be higher than doses that were estimated in previous RDAs for the same condition, thus providing maximum benefit of the doubt to the veteran."
- The doses "will be high enough to ensure that the reported dose is not less than the veteran's true upper bound (95th percentile) dose."
- The reported doses are either well above or well below the dose that could result in service-connected disability determinations for the claimed medical condition, considering age at exposure and age at diagnosis.
- The "assigned expedited UB doses 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."

The effort discussed in this report concentrated on the identification of the participants in each EPG and the development of their exposure parameters and assumptions with the purpose of satisfying the above considerations. Discussions are included concerning methods for assessing whether doses are well above or well below the dose that could result in service-connected disability determinations.

Development of an EPG involves careful application of these VBDR considerations as well as attempts to maximize the number of participants who are considered members of an EPG and

[1] The VA disability compensation program is based on a determination of whether a claimed condition is connected with military service, known as "service connection". The VBDR phrase "result in a successful claim" is taken in this report to mean "service-connected disability determination" or similar term.

candidates for assignment of the EPG doses and their 95th percentile upper bounds. This additional consideration is crucial to providing timely, cost-effective dose reports. In an effort to include as many participants as reasonably feasible in a single EPG, implementation of the final VBDR consideration listed above can be helpful. For example, a participant who departed a Pacific test site before the occurrence of a fallout event to which other members of the EPG were exposed may nonetheless be considered a member of that EPG and be assigned the EPG doses that include the contribution from the fallout event. This results in an apparent inconsistency between the veteran's individual dose and his assigned EPG dose. However, because these assigned doses are not individualized but are derived from worst-case composite scenarios, they are acceptable for the purpose of providing high-sided estimates for all members of an EPG as long as they are well below the doses that could lead to service-connected determinations. This approach supports the conclusion that the EPG upper-bound dose is greater than the dose the veteran actually received.

The EPG upper-bound doses, thus derived with an approach that produces large and sometimes impossible overestimates of dose to certain organs and tissues, are not suitable for cases where these doses are near or greater than the minimum dose required for service-connected determinations (i.e., Outcomes 2 and 3 mentioned in Section 1.1.1). Doses that could lead to service-connected determinations should be calculated using information specific to the veteran's circumstances of exposure while using parameters and assumptions that produce 95th percentile upper-bound doses and that assure the veteran receives full benefit of the doubt.

1.2 Purpose and Scope

The purpose of this report is to document the technical basis for the NTPR expedited process for cases that are expected to produce EPG upper-bound doses that are well below the minimum doses required for service-connected determinations. This technical basis derives from a study that was designed and performed to:

1. Review available NTPR data on veteran radiation exposures and reported doses to determine their suitability for serving as the basis for expedited doses.
2. Apply a process for estimating the association between service-related radiation exposure and medical conditions that is consistent with the one used by the VA in adjudication of claims to assess whether proposed doses are well below those that could result in service-connected determinations.
3. Develop standardized lists and lookup tables of diseased organs, organs with reported internal dose coefficients, and cancer risk models to ensure consistency in processing.
4. Develop approaches to expediting cases based on the concepts of "highest-dose cohorts" augmented with maximizing exposure pathways and dose parameters for broadly defined exposure groups of participants.

5. Carry out a pilot phase for proof of concept and to demonstrate the methodology using sample groups of participants, and provide preliminary results of the proposed methods in an interim report.
6. Recommend a strategy for selecting groups of participants for expediting cases as well as the best approach to developing bounding scenarios of exposure.
7. Complete EPG dose estimates for the broadest number of participants in expedited cases using the methods and approaches developed in this study.

Doses for some tissues and organs were not included in these EPG dose assessments. Expedited doses to the skin and lens of the eye, developed following the VBDR recommendations of July 2006 (VBDR, 2006) and March 2007 (VBDR, 2007a) were already at a high level, reflecting the extreme uncertainty associated with their calculation. These previously calculated doses already are likely to result in a VA service-connected determination. Doses to the female breast, uterus, and ovaries were not evaluated because the participants in the VA disability program are overwhelmingly male, reflecting the military personnel practices of the post-World War II occupation of Japan and atmospheric nuclear weapons-testing eras. Doses from initial gamma and neutron radiation exposures also were not included in the EPG dose assessments, but are specifically addressed in Weitz and Egbert (2010).

This report includes discussions of the following: characterization and selection of groups of exposed participants to form EPGs; the need for and achievement of consistency among references to organs used in the dose reconstruction process and the cancer types (models) used in the National Institute of Occupational Safety and Health-Interactive RadioEpidemiological Program (NIOSH-IREP) software program, which is used by the VA in adjudicating claims for service-connected determinations for cancer; approaches to demonstrating that estimated EPG doses are credible and greater than those received by any member of the EPG; and details of an approach to evaluating whether the EPG doses are well below the dose that could result in a service-connected determination. The process and decision-making for using the EPG approach to expedited processing of NTPR RDAs is outside the scope of this report.

1.3 Organization and Content of Report

This report builds on the approaches, analyses, and results of pilot testing reported in an interim report (DTRA, 2010b). Section 2 addresses the relationships between claimed medical conditions, target organs, and NIOSH-IREP cancer risk models. Section 3 discusses methodologies for identifying participant groups and maximizing scenarios for expedited processing. Section 4 provides the rationale for the proposed EPGs. Section 5 provides summaries of the proposed EPGs that have been completed. Finally, Section 6 provides a summary and conclusions about the results obtained. This report is supplemented by a companion volume called the EPG Compendium (DTRA, 2011), which contains detailed discussions about each proposed EPG.

2.

Target Organs, Cancer Models, and Screening Doses for Claimed Medical Conditions

A major goal of the dose reconstruction process is to apply sound, scientific methodologies to the calculation of dose estimates for organs associated with medical conditions identified in claims filed with the VA. Appropriate target organs must be identified that are associated with specific medical conditions in order to estimate organ doses. VA uses those target organ dose estimates to evaluate whether it is as least as likely as not that a medical condition was caused by a given radiation dose and to document the results in a medical opinion.

VA's assessment process differs for cancers and non-cancers. For cancers, VA uses the NIOSH-IREP software (NIOSH, 2002) to calculate a PC, which is the probability expressed as a percentage between 0 and 100 percent, that the radiation dose produced the diagnosed cancer in the veteran. In adjudicating claims for service-connection, VA uses the upper 99th percentile of PC, taking uncertainties in the estimated cancer risk to the individual into account. The NIOSH-IREP software associates cancer risk models developed on the basis of radioepidemiological data with the dose, age at exposure and age at which the cancer was diagnosed. The radioepidemiological models used are those developed by a working group of the Centers for Disease Control and Prevention (CDC) and the National Cancer Institute (NCI) that was mandated by Congress to update the 1985 NIH Radioepidemiological Tables as described in Land, et al. (2003).

For non-cancers, VA reviews the medical literature and consults with experts as needed to assess the potential that the radiation dose contributed to the medical condition.

2.1 Designation of Organs, Tissues and Diseases

A review of NTPR RDA records, documentation of the Fallout Inhalation Ingestion Dose to Organs (FIIDOS) internal radiation dosimetry computer code, and NIOSH-IREP documentation indicates that there are different sets of terminology used to describe:

- The claimed medical conditions and the associated tissues and organs in the NTPR Nuclear Test Review Information System (NuTRIS) Data Dictionary (DTRA, 2007a).

- The organs with published, consensus values of radiation dose coefficients (ICRP, 1996; ICRP, 2002) used to generate dose conversion factors in NTPR dose reconstructions using the FIIDOS computer program (Raine et al., 2007).
- The cancer types (models) used in the NIOSH-IREP software (NIOSH, 2009).

The following sections discuss each of these terminology sets and their inter-relationships.

2.2 Relationship of NTPR NuTRIS Organ Codes and NTPR Standard Organs

The NTPR NuTRIS Data Dictionary (DTRA, 2007a) contains 265 distinct entries in the "Organ Codes" field with an equal number in the corresponding "Description" field. Presumably, these entries have been developed to accommodate information contained in VA requests to DTRA for dose information. Of the 265 entries, 132 were related to skin sites, which are not within the scope of this study and are not discussed further.

The calculation of radiation dose to organs and tissues from internally deposited radioactive materials requires dose conversion factors that relate a committed equivalent dose to an organ to the quantity of radioactive material that is taken into the body through inhalation, ingestion or other routes of entry. To accomplish this, NTPR calculates dose conversion factors for a consolidated inventory of radionuclides for 23 organs and tissues for which dose coefficient values have been published (ICRP, 1996 and 2002). These 23 organs are referred to as NTPR Standard Organs. For this report, three of the organs—ovaries, uterus, and skin—are not used, leaving 20 organs that must be related to 133 NTPR NuTRIS Organ Codes. Since there are many more NuTRIS Organ Codes than NTPR Standard Organs, choices are made to select the most appropriate NTPR Standard Organ to represent each NTPR NuTRIS Organ Code for which there is no corresponding NTPR Standard Organ (DTRA, 2010a). These representative NTPR Standard Organs are called NTPR Surrogates. Table A-1 of Appendix A lists the NTPR NuTRIS Organ Codes, with their NTPR Standard Organs, or Surrogates.

2.3 Organs and Cancer Models Used for IREP/PC Screening

NIOSH-IREP contains 32 cancer models designated by ICD-9 Code (NIOSH, 2009). Of these, five models for malignant melanoma of skin, basal cell carcinoma of skin, squamous cell carcinoma of skin, cancer of the ovary, and cancer of the female genitalia other than the ovary are not considered in this report, leaving 27 cancer models that must be mapped to NTPR NuTRIS Organ Codes to estimate PC values for each NTPR NuTRIS Organ Code. This mapping was accomplished using the judgment of a radiation oncologist, who is certified in Therapeutic Radiology by the American Board of Radiology, to match cancer models with the most appropriate NTPR NuTRIS Organ Code. Table A-1 of Appendix A lists these cross-references.

2.4 Cross Reference between VA and DTRA Lists

The NTPR NuTRIS Organ Codes reflect information provided in VA claims documents and possibly in personal inquiries for participation and dose information. Many of these NuTRIS Organ Codes use replicate terms for a particular diseased organ or tissue or are not specific enough to make reliable selections of the NTRP Standard Organ(s) and the NIOSH-IREP cancer model. In order to address replicates and non-specific codes Table A-1 of Appendix A lists both the "Current NTPR NuTRIS Organ Codes" and also "Proposed NuTRIS Organ Codes." The latter provides a set of standardized NTPR NuTRIS Organ Codes for use in all RDAs—expedited or full—that establishes the foundation for consistent recording of the information and selection of NTPR Standard Organs and NIOSH-IREP cancer models. Once adopted, this collection of codes could also form the basis for automated selection of the NTPR Standard Organs for dose reconstruction and selection of the appropriate NIOSH-IREP Cancer Model, based on medical diagnostic (ICD-9 Codes) (CDC-CMMS, 2010).

2.5 Screening Dose and Estimation of Probability of Causation

The PC values corresponding to the EPG doses can be useful in determining whether the proposed doses are appropriate for making service-connected determinations. A screening dose, which is a dose that produces a PC value of 50 percent at the upper 99th percentile, taking uncertainties in the cancer risk models into account, can serve as a benchmark to help assess the suitability of the assignment of doses through expedited processing. The following sections summarize the cancer risk models used in NIOSH-IREP, review VA's use of radiation doses in reaching service-connection decisions, explain the meaning of a dose that is "well below the dose that could lead to a service-connected determination," and discuss "screening dose" and its relevant parameters.

2.5.1 VA's Estimation of Probability of Causation

The VA's Office of Public Health and Environmental Hazards (OPHEH), Veterans Health Administration, renders medical opinions about the association of cancers with radiation dose for claimant cases. Since April 2005, the medical staff of OPHEH has been using the latest version of NIOSH-IREP to evaluate PC. OPHEH uses doses reported by DTRA in evaluating cases related to NTPR participants. In so doing, it evaluates reported doses so that "when a range of dose estimates are provided, exposure at the highest level of the dose range will be presumed [38 CFR 3.311(a)]" (Otchin, 2007). This means that when DTRA reports both a mean dose and an upper-bound dose, VA would use only the upper-bound dose (without uncertainty) as a point estimate of dose to calculate a PC using NIOSH-IREP.

Since NIOSH-IREP is designed to calculate PC using doses for each radiation type and DTRA reports doses in this format, OPHEH enters the highest dose for each radiation type, assumed to be the upper-bound doses reported by DTRA, as "constants" rather than as dose distributions and uses the following conventions for selecting radiation energy (designated as E):

- External gamma doses are entered as acute photon doses of E > 250 keV.
- External neutron doses are entered as chronic neutron doses of E = 0.1–2 MeV.
- External beta doses are entered as acute electron doses of E > 15 keV.
- Internal gamma doses are entered as chronic photon doses of E > 250 keV.
- Internal beta doses are entered as chronic electron doses of E > 15 keV.
- Internal alpha doses are entered as chronic alpha doses.
- Combined internal beta/gamma doses are entered as chronic photon doses of E > 250 keV or chronic electron doses of E > 15 keV in separate NIOSH-IREP runs.

2.5.2 Determination of Screening Doses

One approach to evaluating the potential results of service-connected determinations for proposed EPG doses is to calculate the PC for each claimed organ with cancer and its associated dose. This approach would require substantial effort. An alternate approach is to use the so-called screening doses reported in Kocher and Apostoaei (2007), which DTRA employed during development of the currently used processes for expediting RDAs. The variation of PC with dose, age of the individual at exposure and the time between exposure and diagnosis of the disease is dependent on the cancer risk model included in the NIOSH-IREP software.

Kocher and Apostoaei (2007) discussed the nature of the cancer risk models used in NIOSH-IREP for four groups of cancer types and developed tables of screening doses at various ages at exposure and elapsed times between exposure and diagnosis of the disease for 34 cancers. Table 1 below lists the cancer types included in each group, and summarizes the model characteristics of each of the four cancer groups discussed in detail in Kocher and Apostoaei (2007). Cancers of the skin and cancers of female organs discussed in Kocher and Apostoaei (2007) are not included in Table 1 because currently used expedited processes for those cancers are established and are not part of the scope of this report.

2.5.3 Variations in Screening Dose Values

The risk of cancer to organs and tissues in Groups 1 and 2 vary with age at exposure and age at diagnosis of the cancer. Screening doses for these cancers also show a similar age-dependence. This allows screening doses to be calculated for various combinations of age at exposure and attained age at diagnosis—or equivalently the elapsed time between exposure and diagnosis. Although there may be many possible approaches to selecting values of these age-related parameters for use in calculating screening doses, two that seem reasonable for

Table 1. Categories of Cancer Risk Models Incorporated in NIOSH-IREP from Kocher and Apostoaei (2007)

Category	Cancer Types*	Primary Risk Model Characteristics
Group 1	All digestive cancers other than stomach, colon and rectum; liver; breast*	Risk depends on age at exposure, attained age, and sex
Group 2	Oral cavity and pharynx; esophagus; stomach (male only); colon; rectum; gallbladder; pancreas; lung (including trachea and bronchus); respiratory other than lung (e.g. nasal cavity, larynx); bone; all connective tissue; all male genitalia (including prostate); bladder; kidney and other urinary organs except bladder; eye; nervous system (including brain); endocrine glands other than thyroid; other and ill-defined sites; lymphoma and multiple myeloma	Risk depends on age at exposure, attained age, and sex. Model dependencies on age parameters differ from Group 1, and lung cancer risk depends on smoking history.
Group 3	Lung (including trachea and bronchus)	Risk is independent of age at exposure and attained age; risk of lung cancer depends on sex and smoking history. Lung cancer model differs from Group 2; both models are in current version of IREP used by VA
Group 4	Thyroid; leukemia (other than chronic lymphocytic leukemia, CLL), acute myeloid leukemia (AML), chronic myeloid leukemia (CML), and acute lymphocytic leukemia (ALL)	Unique risk model for each cancer type.

* Six cancer types included in Kocher and Apostoaei (2007) are not included in this study: stomach (female only) (Group 1); ovary (Group 2); all female genitalia except ovary (Group 3); malignant melanoma; non-melanoma skin cancers; and lung cancers due to radon exposure (Group 4).

determining screening doses for any cancer type (model) are as follows: 1) use the lowest dose for a given cancer for all combinations of age at exposure and attained age, or 2) use doses for a representative age at exposure and representative attained age. The lowest screening doses for many cancers are observed for exposures at age 18 and at times from exposure to diagnosis of the cancer that range from about 5 to 10 years, with a few exceptions (Kocher and Apostoaei, 2007). Minimum doses for cancers in Groups 1 and 2 are typically observed at 10 years after exposure and increase thereafter.

The risks and associated screening doses for cancers in Groups 3 and 4 have more varied time dependencies. For cancers in Group 3, screening doses decrease with elapsed times after exposure of 10–15 years. For all leukemias (Group 4), the lowest screening doses are observed at 5 years after exposure. For thyroid cancer (Group 4), the lowest screening dose occurs at 10 years following exposure and remains constant thereafter. Many of these screening doses are within the range of the doses received by some NTPR participants, but correspond to ages at diagnosis that are well before any of the attained ages at diagnosis for participants who have filed claims.

Kocher and Apostoaei (2007) calculated screening doses at ages at exposure ranging from 18 to 40 or more years, as well as for times between exposure and diagnosis of disease ranging from 5 to 30 or more years depending on the cancer type. Examples of the variations in the values of these screening doses are shown in Table 2, which lists the lowest screening doses and the screening doses at attained age 50 for exposure at age 18 for each of the 27 NIOSH-IREP organ/tissue/disease categories included in this report. These screening doses can be useful for assessing whether a given dose corresponds to a PC value of 50 percent at the 99th percentile. However, a dose that is slightly above or slightly below the screening dose may not provide a definitive answer about service-connection for several reasons. Exposures occurring over several years or involving significant doses from alpha particles or neutrons may produce different values of PC than those calculated under the assumption that the total dose was due to an acute exposure to photons with energy greater than 250 keV as was assumed in Kocher and Apostoaei (2007).

2.5.4 Definition of Doses well below a PC of 50 Percent

To determine whether an organ dose calculated using expedited procedures satisfies the condition that the dose is well below the organ dose that could result in a service-connected determination; the dose can be compared with a screening dose for the cancer that is the subject of a claim. Selection of a screening dose calculation for an age at exposure of 18 and elapsed times of 30 or 40 years represents a reasonable description of NTPR participants who were mostly exposed at young ages (18–22) during 1945 to 1962, and who began, or would begin experiencing cancers 30 to 50 years later (1992 to 2012) at attained ages of 48–72.

In addition to taking into consideration the variation in screening dose with age at exposure and time elapsed between exposure and diagnosis of disease, evaluators must consider the inaccuracy in calculating PC related to the use of a finite sample size and changes in the random seed used to start the Monte Carlo process in NIOSH-IREP. One approach is to select a range of PC values around 50 percent. To be acceptable, a reportable dose from expedited procedures should be well below the dose that would not lead to a service-connected determination as represented by the dose corresponding to the lower value of the selected PC range for cancers. Cases with doses derived from expedited procedures that are greater than this lower value would be processed using full dose assessment procedures that take into account details of the individual exposure scenario, and use methods that mitigate the inaccuracies in calculating PC.

Table 2. Screening Doses for NIOSH-IREP Organ Categories (Kocher and Apostoaei, 2007)

Organ Categories	Lowest Screening Dose (rem)*	Screening Dose (rem) at Age 50†
Oral cavity and Pharynx	32	98
Esophagus	12	35
Stomach	9.0	27
Colon	12	39
Rectum	36	110
All digestive (other than esophagus, stomach, colon, rectum/anus)	22	66
Liver	4.0	11
Gallbladder	6.0	17
Pancreas	31	89
Lung (never smokers)	18	45
Other Respiratory	34	100
Bone	10 (5 years)	48
Connective tissue	16	50
Male breast	12	53
All male genitalia	21	60
Bladder	16	49
Urinary organs, excluding bladder	14	46
Eye	16	49
Nervous system	32	95
Thyroid	7.5 (≥ 10 years)	7.5 (≥ 10 years)
Other endocrine glands	14	45
Cancers of other and ill-defined sites	16	50
Lymphoma and multiple myeloma	22	61
Leukemia, excluding CLL	1.9 (5 years)	41 (30 years)
Acute Lymphocytic Leukemia	0.24 (5 years)	24 (30 years)
Acute myeloid leukemia (AML)	5.8 (5 years)	29 (30 years)
Chronic myeloid leukemia (CML)	1.4 (5 years)	57 (30 years)

* Calculated for age of exposure of 18 and elapsed time of 10 years (or elapsed time shown).

† Calculated for exposure at age 18 and attained age of 50 (or elapsed time shown).

To be useful, doses that result from the EPG approach to expediting RDAs proposed in this report must be well below the dose that could result in service-connected determinations. To be credible, these doses should be based on specific criteria that are transparent and that veterans understand. Precedent exists in other federal compensation programs that can offer an example of such criteria. NIOSH uses efficiency methods for reducing efforts required to perform credible dose reconstructions performed under the Energy Employees' Occupational Injury Compensation Program Act (EEOICPA). This program uses a PC range of 45 to 52 percent for determining whether dose reconstructions can be completed using efficiency methods or require full dose reconstructions (ORAU, 2007). The lower value (45 percent) could serve a similar purpose for NTPR RDAs. The doses associated with PC values of 45 percent for cancers of

interest were found to be about 20 percent less than the doses that produced a PC value of 50 percent. To provide an additional margin of error and to ensure benefit of the doubt to the veteran, this report defines "well below the dose that could result in compensation;" i.e., results in a service-connected disability determination as the dose that produces a PC value of less than 40 percent for exposure at age 18 and diagnosis of cancer at either age 50 or after an appropriate elapsed time following exposure as shown in Table 3. This dose is defined as the "limiting dose. A comparison of screening doses and limiting doses for all organs considered in this report is presented in Table 3.

2.6 Role of Screening Doses for Non-Cancers

NIOSH-IREP does not address all medical conditions that could be the subject of claims filed with VA. For example, benign neoplasms and deterministic effects of radiation are not addressed. Therefore, screening doses are not available for claims involving non-cancer conditions.

For service-connected determination cases claiming disorders, for which that NIOISH-IREP does apply, OPHEH uses sources such as the National Research Council (NRC) Biological Effects of Ionizing Radiation (BEIR) reports, the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile for Ionizing Radiation, major textbooks, and key scientific papers to formulate medical opinions and make service-connected determinations. (Otchin, 2007) EPG doses could be reported in response to VA requests for dose information for cases involving non-cancers.

Table 3. Organ Doses Corresponding to the Limiting Dose (PC=40 percent) and Screening Dose (PC=50 percent) for Selected Cancers

Cancer of Organ	Limiting Dose (rem) at 40% PC*	Screening Dose (rem) at 50% PC*†
Oral cavity and Pharynx	66	98
Esophagus	22	35
Stomach	18	27
Colon	26	39
Rectum	72	110
All digestive (other than esophagus, stomach, colon, rectum/anus)	44	66
Liver	7.7	11
Gallbladder	11	17
Pancreas	61	89
Lung (never smokers)	30	45
Other Respiratory	67	100
Bone	32	48
Connective tissue	34	50
Male breast	36	53
All male genitalia	41	60
Bladder	33	49
Urinary organs, excluding bladder	31	46
Eye	32	49
Nervous system	64	95
Thyroid	5.1	7.5 (≥ 10 years)
Other endocrine glands	30	45
Cancers of other and ill-defined sites	34	51
Lymphoma and multiple myeloma	41	61
Leukemia, excluding CLL	29	41 (30 years)
Acute Lymphocytic Leukemia	14	24 (30 years)
Acute myeloid leukemia (AML)	20	29 (30 years)
Chronic myeloid leukemia (CML)	41	57 (30 years)

* PC calculated for exposure at age 18 and attained age of 50 (or elapsed time shown).

† From Kocher and Apostoaei (2007).

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3.

Methodology for Identifying Participant Groups and Maximizing Scenarios for Expedited Processing

Three approaches were evaluated during the initial phase of this study to update and document the technical basis for estimating organ radiation doses for expedited processing (DTRA, 2010b). The first approach relied on the direct use of historical RDA dose results without regard to the exposure scenarios of their associated cases. This approach established the expedited processing doses in use at the time this report was being written. These expedited processing doses will be referred to as "current" or "currently used," to distinguish them from the proposed EPG doses discussed in this report and documented in its associated EPG Compendium (DTRA, 2011). These currently used doses are based mostly on the set of doses available in the NTPR NuTRIS database from fully developed RDAs completed between March 2004, following the publication of the 2003 NAS report (NAS/NRC, 2003), and March 2006. In the pilot phase of the present evaluation and update, dose data from non-expedited RDAs completed between April 2006 and March 2010 were added to the first data set, and the direct use of historical doses was reanalyzed. Review of the RDAs associated with currently used doses for expedited processing revealed that the methodology and dose assignments should be updated using information developed since this approach was established (DTRA, 2010b). The second approach evaluated uses of historical dose results to identify cases with the highest reported doses that are relevant to large groups of participants. This approach differs from the first approach in that it does not combine all historical doses into a single group. Rather, it identifies historical doses that can be assigned for groups of individuals with similar participation and exposure scenarios. The last approach, which was the one selected for further analysis as an alternative to the currently used method (first approach), develops doses for expedited processing based on maximizing exposure scenarios for large groups of participants.

The selected scenario-based approach uses DTRA-approved dose reconstruction methods to determine group-specific external and internal doses. These doses are estimated using radiation survey data primarily and, where feasible, film badge records. The reasons for using exposure rate data or measurement-based estimates of such to calculate EPG doses, for the most part, are as follows:

- Individual film badge doses are not representative of doses assignable to EPGs.
- Personnel in a cohort with high film badge doses are considered likely outliers that were exposed to additional sources or higher levels of radiation than the generic group/cohorts for which expedited processing is designed.

- Participants in a cohort with high film badge doses are likely to be excluded from expedited processing when their exposure information is reviewed.
- Film badge dosimetry often does not cover the whole duration of participation of the entire membership of an EPG.
- A quantification of exposure rate as a function of time is needed to reconstruct corresponding internal doses. This exposure rate function is more directly and accurately estimated from time-specific exposure rate measurements than from film badge data, the latter representing the integration of exposure rate over an often substantial period of time.

3.1 Limitations of the Direct Use of Historical Doses from Previously Assessed Cases

The currently used doses, as derived from the first approach introduced above, were developed in 2007 using dose distributions from previously completed full RDAs. For the external gamma dose, the maximum dose from all previously-completed Nevada Test Site (NTS) or Pacific Proving Ground (PPG) cases was adopted for expedited processing as the dose to be assigned to an individual who participated at the relevant location (i.e., NTS or PPG). The selection of the initial neutron doses currently used in expedited processing was not clearly documented. The method adopted for internal doses consisted of sorting the historical dose estimates developed in full RDAs into groups of organs and tissues. The organs or tissues in each group were selected on the basis of cancer types or models used in the NIOSH-IREP software described in Section 2 and hence would generate the same probability of causation for the same dose. The maximum historical internal doses for each group of organs or tissues were adopted as the doses to assign under expedited processing to any NTPR claimant with a relevant disease associated with the organs or tissues of that group (DTRA, 2007b). Because the number of completed cases for each group of organs and tissues was generally small except for prostate cancer, distinction was not made between NTS and PPG, and all available doses were analyzed in aggregate for each organ group. Exceptions were established where a case needed to undergo further review to address instances of special exposures that are based on a participant's documented activities and statements that could result in higher doses. Participants at Hiroshima and Nagasaki, as well as those who participated in more than one test series were processed through a more in-depth review and/or full RDAs.

However, as reported in DTRA (2010b), the direct use of previously-completed RDA dose estimates without regard to the scenario of activities results in doses that are unlikely to be representative of radiation exposures for the majority of participants. It is also important to note that maximum internal doses that are based solely on historical dose values without consideration of the associated exposure scenarios are inherently inconsistent across organs and participant groups; that is, the maximum internal doses do not reflect the relative magnitude of doses that would be expected from one organ group to another if the exposure scenario were the same for all groups. Furthermore, for cases where doses may potentially be greater than the respective maximum historical doses selected for use in expedited processing, current procedures require the preparation of full RDAs. If a more recent full RDA produces an external or internal

dose that is higher than the existing historical maximum used for expedited processing, the latter dose would need to be changed to the newer maximum value. Lastly, it is not obvious whether historical maximum mean doses, maximum upper-bound doses, or some other values should be used as the assigned external and internal doses under the current expedited processing procedures.

To illustrate the inconsistencies that could result from the direct use of historical dose results, consider two land-based participants from the same unit at the PPG who performed similar activities but submit claims of diseases to two different organs. Using current expedited processing procedures, the two cases would likely be assigned internal doses that are based on two different exposure scenarios, each of which differ from the participants' scenarios and are mutually inconsistent. Assume the first claim is for cancer of the oral cavity, for which the surrogate organ is "ET region," and the second is for cancer of the kidney. For the claim involving the oral cavity, the maximum historical beta-plus-gamma internal dose is 7.4 rem. This dose is derived from a scenario involving inhalation of fallout that was resuspended from ship surfaces during decontamination activities after heavy fallout from Shot TEWA, Operation REDWING. For the claim involving the kidney, the maximum historical beta-plus-gamma dose is 0.004 rem. This dose is associated with the case of a veteran who served in a patrol squadron aircraft during REDWING and had minor radiation exposure and internal intake of contaminated materials while stationed at Kwajalein. Furthermore, the external gamma dose is 4.3 rem for the first case and 0.36 rem for the second. Additional inconsistency may occur for alpha doses because the highest alpha doses for the two organs would likely not be associated with the same cases as those for the highest beta-plus-gamma doses (DTRA, 2010b).

The example above demonstrates how two claimants with similar potential exposure pathways are assigned doses that could be based on four widely varying scenarios of participation and radiation exposures. It is also clear that maximum doses from previously assessed cases are largely associated with special exposure scenarios for which expedited processing may not be applicable.

Moreover, current doses were selected based on an organ's cancer model classification from the NIOSH-IREP software rather than the FIIDOS-derived Standard Organs list used in NTPR dose reconstructions (DTRA, 2010a). An example of a consequent discrepancy is the doses currently utilized in expedited processing for the organs rectum and colon. The maximum historical doses used in current expedited processing are 2 rem and 8 rem for beta-plus-gamma radiation to the colon and rectum, respectively. However, in full RDAs performed in the NTPR Program, internal doses to the colon and rectum are both estimated using lower large intestine as the surrogate FIIDOS organ. Therefore, an individual claiming disease for the rectum and colon would normally receive the same dose to both organs based on standard dose reconstruction methods for full RDAs that would calculate internal doses using FIIDOS dose conversion factors for the lower large intestine.

Despite the limitations cited above for the direct use of historical RDA doses, such records can be useful in some situations to identify a large enough group of cases with comparable exposures. It is also appropriate to check the database of previously completed full RDAs to verify that the doses used in expedited processing are bounding for the defined group and ensure that cases with greater doses reflect special exposure scenarios that are excluded from

consideration for expedited processing. Finally, historical dose results and individual RDAs are useful in providing the source for exposure scenarios and input parameter estimates, as well as pathway selection for EPGs.

3.2 Expedited Processing Groups and Scenario-Based Dose Estimation

Scenario-based EPG doses were developed using available information and publications on atmospheric testing and military participation from 1945 to 1962, film badge dosimetry records, and previously-completed RDAs. The process of developing doses for an EPG consists of the following steps:

- Identify EPG cohorts based on similarity of scenario activities and exposure pathways of their members.
- Select a "highest-dose cohort" that forms the generic basis for the scenario of participation and radiation exposure, potential exposure pathways, and related radiation environments.
- Modify dose components for specific exposure pathways using the scenario of exposure of the cohort(s) within the EPG that results in the highest dose for each specific dose component.
- 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.

The scenario-based EPG radiation assessment model for external doses is illustrated in Figure 1, and the concepts and steps listed above are described in detail in the subsequent sub-sections. Using the above methodology guarantees that the doses assigned to an EPG bound the doses for each one of its members, even though not every exposure pathway or scenario of activities is applicable to all members of the EPG.

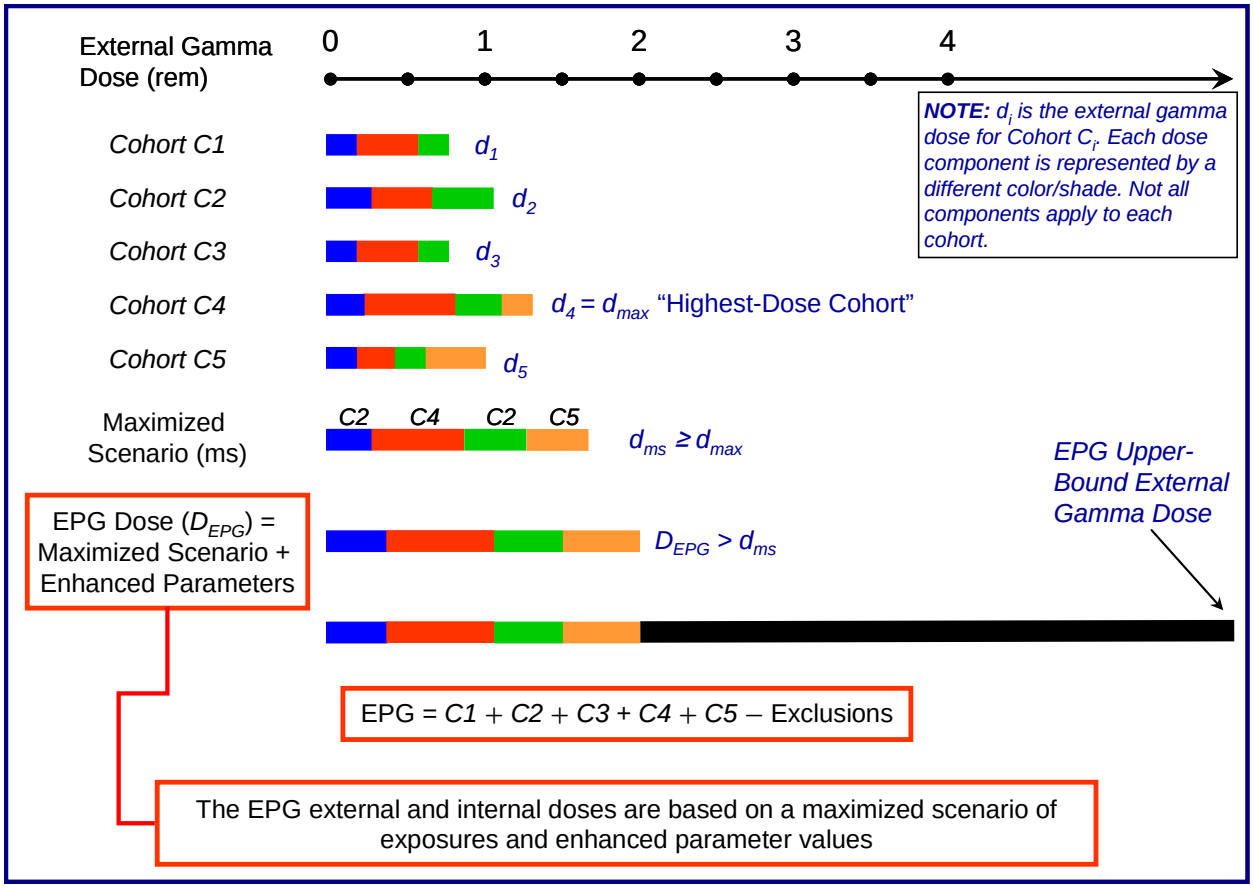

Figure 1. The Concept of Assessing Doses for Expedited Processing

3.2.1 Definitions and Concepts

A scenario-based EPG radiation dose assessment provides results using documented cohort activities and exposures with additional high-siding adjustments that produce highly conservative doses for a group of cohorts. The highly conservative estimates can be assigned to large numbers of participants in the group of cohorts whose documented exposures are comparable to or smaller than those used to calculate the doses for the EPG. This means that the realistic doses of any member of an EPG, if calculated using a detailed assessment (full RDA), should be lower than the doses for that EPG. These groups can be as large as reasonable, with larger EPGs resulting in fewer doses to be estimated and maintained.

An EPG consists of one or more cohorts that participated in atmospheric nuclear tests and performed activities that would have resulted in doses that are lower than the overall EPG doses. The aim is to use criteria so that all possible exposure pathways and radiation sources that are applicable to a cohort are combined to estimate the EPG doses. Therefore, to belong to an EPG, cohorts were selected based on the following criteria:

1. Commonality of activities and radiation environments.
2. Comparability of types of radiation (e.g., external gamma, internal alpha, and internal beta/gamma).
3. Similarity of exposure pathways.
4. Duration of participation and timing with respect to detonations.
5. Likelihood that doses are well below the screening doses for all or most non-presumptive cancers.

The satisfaction of Criterion (5) for large EPGs was verified based on a sequential process in which cohorts that were originally represented in separate EPGs were pooled together based on how the overall (external plus internal) doses of the higher doses EPG compared to the screening doses for most non-presumptive cancers. In another case, the compositions of two EPGs for Operation CASTLE ship-based personnel were re-evaluated, and cohorts were moved from the high-dose EPG to the low-dose EPG using Criterion (5) to better define the two groups.

In relying on Criterion (5) to develop EPGs, attempts were made to minimize the number of EPG/organ combinations that would not satisfy the condition that the overall doses are well below the screening doses, as discussed in Section 2.5 and 3.3. Therefore, for an EPG/organ combination in which the overall dose is not well below the screening dose, the combination would not qualify for expedited processing. The results of these comparisons are discussed in Section 5.

Based on these criteria, NTPR participants were grouped into compatible EPGs that are listed in Appendix B and described in detail in the EPG Compendium (DTRA, 2011) that accompanies this report, with the rationale for major groupings discussed in Section 4. Using scenario-based dose assessments guarantees adherence to the following principles:

- Representative scenarios are used as the basis for defining exposure pathways.
- External doses incorporate maximized exposure scenarios and input parameter values.
- Internal doses are based on an assumed concurrent accrual with external doses using maximized intakes where there is potential for internally-deposited contaminants.
- Consistency exists between alpha and beta-plus-gamma internal doses, which are based on the same exposure scenario.
- Internal doses among organs are in the correct relative magnitude given the same scenario of exposure.
- Uniformity in the treatment of upper-bound doses is maintained.
- Approved NTPR standard methods and procedures are used as the basic approach to estimate the doses.

3.2.2 The "Highest-Dose Cohort" and Substitute Cohorts

The estimation of doses for an EPG requires identifying potential activities and the corresponding exposure pathways that bound the doses to all the members of the group. To develop such exposure pathways, a "highest-dose cohort" is first selected from all the cohorts that comprise the EPG based on the highest documented estimates of external gamma dose from residual radioactivity. These gamma radiation doses do not include initial gamma radiation, which is discussed later in this section.

The scenario of participation and radiation exposure of the highest-dose cohort forms a starting point for estimating the EPG doses. To capture potentially higher doses for specific pathways, each component of both the external and internal doses is evaluated to determine if similar activities of participants from other cohorts of the EPG would have resulted in a higher dose than that of the highest-dose cohort. If a cohort dose is expected to be higher for any component of external or internal doses, that cohort becomes the basis for the specific exposure pathway and corresponding dose component for the entire EPG. Once all potential pathways are evaluated, components of the external and corresponding internal doses are assembled and modeled using the dose reconstruction methods described in DTRA (2008 and 2010a). These doses are further increased (see next section) to ensure that they are limiting for all EPG members.

As explained above, the external and internal doses for the highest-dose cohort and any substitutions thereof are estimated based primarily on radiation survey data. In a few instances, film badge data are used to estimate some or all components of an EPG external gamma dose. This is suitable when members of the highest-dose cohort have been similarly exposed (i.e., reflected by a narrow film badge dose distribution) or when reliable radiation survey data are unavailable. The use of film badge dosimetry in estimating external doses is discussed for specific EPGs in the EPG Compendium (DTRA, 2011).

3.2.3 Maximizing the Doses

As described in the previous section, the external and internal doses derived for an EPG from the scenario of exposure of the highest-dose cohort can be maximized by substituting dose components for specific pathways. A substitute scenario of exposure is derived from another cohort that received a higher dose by a specific pathway than the corresponding dose component of the highest-dose cohort. This process results in higher doses from maximizing single exposure pathways and relevant dose components.

For example, service observers who participated in a single shot at or after Shot BADGER during Operation UPSHOT-KNOTHOLE were exposed to residual radiation from Shot BADGER fallout at Camp Desert Rock (CDR) for a few days. The highest-dose cohort of an EPG consisting of all observer and maneuver troops of all operations carried out at the NTS is the Battalion Combat Team Able (BCT-A) at Shot SIMON during Operation UPSHOT-KNOTHOLE. The dose for this highest-dose cohort would normally be estimated for this pathway based on the number of days the cohort remained at CDR after fallout from Shot

BADGER was deposited. A more conservative dose can be estimated if the duration of exposure is extended to the end of the operational period of Operation UPSHOT-KNOTHOLE. This substituted scenario is valid for most CDR support personnel, many of whom participated as observers at one or two shots during Operation UPSHOT-KNOTHOLE. The dose can be further increased if the entire EPG is credited with exposure to fallout that was deposited from Shot POST during Operation TEAPOT rather than from Shot BADGER of Operation UPSHOT-KNOTHOLE. Cohort substitutions of this type allow the formation of the EPG scenario which results in the highest possible dose to any member for every exposure pathway.

In addition to substituting cohort pathways and supplementing dose components for specific activities and exposure pathways to increase the overall EPG doses, input parameter values can be adjusted so as to increase the calculated doses. When selecting more conservative parameter values, it is imperative to use available published data or critical judgment to ensure that such dose-enhancing values are at or near the upper limit of the range of plausible estimates. For example, assuming a breathing rate of 2.0 m^3 hr^{-1} instead of the default 1.2 m^3 hr^{-1} results in an increase in the internal dose from inhalation. Another parameter that can be used to reasonably increase the doses is the exposure time for being outdoors or topside on a ship.

It is important to recognize that the assignment of EPG doses and upper bounds may not be adequate for all cases. If statements from the veteran reveal an exposure scenario atypical for the EPG to which he was initially assigned, and a technical review indicates that consideration of this scenario could potentially increase his dose to a level comparable to or greater than the EPG dose, then a full RDA may be required. Conversely, if the total upper-bound dose for an EPG is at or above the limiting dose that produces a PC of 40 percent (see discussion in Section 2.5 and 3.3), a full RDA based on an individual's actual scenario of exposure may result in an individual dose that falls below the screening dose.

3.2.4 Identification of Excluded Cohorts and Activities

In general, exclusions consist of specific activities of an individual or one or more cohorts for which the documented scenario of participation demonstrates that the individual or members of the cohort had distinctly higher exposures than those used for the EPG due to special circumstances. These include cohorts for which there is insufficient information that ensures the EPG doses are appropriate. Conversely, certain cohorts that could be identified as members of an EPG may have carried out all of their activities in environments with no potential for radiation exposure, or where the exposures were much lower than for the other members of the EPG. They can be either organized into a separate EPG or processed individually. Cohorts in a participant group are organized into separate EPGs if, given well-documented special activities, their overall exposures are deemed quite distinct, either higher or lower by a significant margin, from the exposures experienced by other members of the EPG. Individual cases involving excluded cohorts or activities that have not been organized as a separate EPG should be referred for further review to determine one of two options:

1. The veteran's likely doses are less than the doses used for the EPG, and therefore the EPG doses can be assigned.

2. The veteran's likely doses are close to or greater than the EPG doses and a detailed RDA should be carried out.

Participants or cohorts excluded from an EPG based on operational activities that are specific to the EPG are listed in Appendix B, with detailed documentation provided in the EPG Compendium (DTRA, 2011). In addition to excluded participants or cohorts that are specific to an EPG, generally excluded activities that apply to multiple EPGs are provided in Table B-1 to Table B-3 of Appendix B of this report.

3.2.5 Combining EPGs

Where warranted, it is also possible, after careful review and analysis, to combine small EPGs to form larger ones. This can be done as long as the doses of the most conservative EPG are well below the screening doses for all or most non-presumptive cancers. If this is not the case, then the combination of smaller EPGs would result in eliminating some cohorts from expedited processing. A possible situation for combining small EPGs into a larger one is the case in which cohorts with similar activities and exposures from one test series are grouped into one EPG and then EPGs for such similar participants from several series are combined into a larger one. As an example, observer and maneuver troop EPGs at each shot within an operation at the NTS were combined into an operation-specific EPG and then combined with observer and maneuver troop EPGs from all NTS operations into a single EPG.

3.3 Applicability of EPG Doses for Expedited Processing

3.3.1 Credibility of Assigned EPG Doses

As described above, when using an expedited process for estimating doses to a group of exposed individuals, the process must clearly show that the dose is greater than the dose that any member of the group could have received. Achieving this goal depends on many factors such as the veteran's specific activities that could have resulted in exposure, the characteristics of the radiation environment, and the uncertainties in the parameters used in the EPG dose calculations. The doses produced for expedited processing are only suitable for submission to VA when these doses are credibly maximized and are well below the screening doses. As stated in Section 2.5, to provide for an additional margin of credibility and be suitable for use in expedited processing, it is recommended that EPG doses produce estimated PCs that are lower than 40 percent. With this proposal, claimants whose doses are derived with expedited processes, and who do not receive favorable service connection decisions, can be assured that the assigned doses are higher than the veteran's actual dose.

3.3.2 Suitability of EPG Doses

During the development of the EPG approach, it was recognized that some EPG organ doses, which are maximized using the methodology described in this section, could be near or well above the screening doses as defined in Section 2. Such doses would not be suitable for use in support of VA's claim decisions. Therefore, a review of EPG doses for suitability must be part of each individual EPG development, and organs with cancers associated with those doses must be identified.

To identify which EPG doses for relevant organs and cancer models are credible, these were compared with the screening doses and the PC values were evaluated. To accomplish this task, the following suitability test of EPG/organ total upper-bound doses was applied:

1. If the overall (upper-bound external plus internal) EPG dose for the relevant organ is higher than the screening dose of the corresponding NIOSH-IREP cancer model, listed in Table 3, the external and internal upper-bound doses estimated for the EPG/organ combination are deemed not suitable for expedited processing.

2. If the overall EPG dose falls between the dose that produces a PC of 40 percent and the screening dose, the PC is calculated using the separate upper-bound doses from each radiation type, and if equal to or greater than 40 percent, the doses for the EPG/organ combination are deemed not suitable for expedited processing.

3. If the PC calculated in step 2 is lower than 40 percent, the doses for the EPG/organ combination are deemed suitable and are proposed for use in expedited processing.

A list of EPG/organ combinations that are recommended for exclusion from expedited processing is compiled for each EPG and are included in the EPG Compendium (DTRA, 2011) and summarized in Section 5. Cases involving an EPG/organ combination found to be unsuitable for expedited processing should be considered for a more comprehensive evaluation.

3.4 Initial Gamma and Neutron Exposures

The initial gamma and neutron doses are to be treated separately from external and internal doses from residual radiations for each cohort or member of an EPG and are not taken into consideration when selecting a "highest-dose cohort" for an EPG. This approach was chosen due to the large variability of exposure to initial radiations by cohorts within some EPGs. Furthermore, these sources are not correlated with the scenario of exposure beyond the first minute after a shot and are not associated with the accrual of internal doses. Initial doses are based on actual scenarios of exposure of the particular cohorts or members of an EPG at the times of detonations. Giving the highest initial doses for any cohort to all members of an EPG would not be credible and would have the potential to cause several additional EPG/organ combinations to become excluded from expedited processing.

A large number of units or cohorts that received doses greater than 1 millirem are documented in Weitz and Egbert (2010). For many of the cohorts grouped into an EPG, the potential for initial radiation exposures did not exist or was insignificant given the locations of participants relative to the sites of the detonations. Conversely, cohorts that received substantial initial doses are likely to be excluded from EPG membership due to their specific types of activities and unique circumstances of exposure to radiation. For example, volunteer observers at some NTS shots and aircrews that were airborne and close to the detonation are excluded from expedited processing and a detailed review of participant cases is required.

Moreover, where significant initial doses have been calculated previously for a cohort that was included in an EPG based on external and internal doses from residual radiation only, the impact of the initial dose upper bounds is evaluated using the overall EPG upper-bound organ doses. In these situations, the cohort's initial upper-bound doses (i.e., gamma and neutron) are added to the EPG upper-bound doses (i.e., external and internal). The overall upper-bound dose, including initial doses, is then compared to the relevant cancer model dose, i.e. "limiting dose" at the 40-percent PC level. The comparison allows determination of the impact of the additional initial doses and whether the overall dose, including initial doses, would still be well below the screening doses. Several high initial dose cohorts in the EPG for Observers and Maneuver Troops and the EPG for Task Force WARRIOR at the NTS were identified and are discussed in the EPG Compendium (DTRA, 2011). Organs with total upper-bound doses, including initial doses, which do not satisfy the well-below the screening dose criterion, are added to the list of organs not recommended for expedited processing for the relevant EPG. This evaluation of EPG doses using the initial doses of cohorts with highest exposure to initial radiation should cover all cohorts in these two EPGs that had some exposure to initial radiation.

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4.

Rationale for the Makeup of the Proposed Expedited Processing Groups

The method of identifying an EPG, as discussed in Section 3, relies heavily on the similarity of activities and exposure pathways among its members. The starting point in formulating EPGs is to combine elements that performed similar duties at the same location (e.g., on a ship, on a residence island at the PPG, or in the NTS forward area during a single test series). As a proof of concept, nine small sample EPGs were evaluated during the pilot phase of this study and are documented in an interim report (DTRA, 2010b).

In the second phase, sample EPGs developed in the pilot phase were expanded by aggregating potentially similar cohort groups. The study team used its substantial experience in performing veteran-specific RDAs to develop a coherent membership for each EPG. For example, the crews of most ships in an oceanic test series experienced similar exposure scenarios and on that basis were incorporated into a single EPG (e.g., Operation GREENHOUSE Ship-Based Personnel). Care was taken to avoid mixing incompatible cohorts—(i.e., those with significantly different exposure scenarios that may have resulted in disparate doses). Each cohort of participants was individually assessed and either 1) incorporated into a compatible existing EPG, 2) made into a separate EPG, or 3) declared an exclusion. Exclusions were flagged for individualized dose assessments.

The EPGs formed in this manner can be quite sizeable. The ship-based EPGs typically have memberships in the thousands to tens of thousands of participants. Similarly, all maneuver, observer and support troops whose participation included post-shot movement toward ground zero in the NTS forward area following one or two test shots were combined into one single EPG with a potential total membership of over 40,000 participants.

4.1 Participants in the Oceanic Series

The United States conducted 106 nuclear weapon tests at locations in the Pacific Ocean during nine operations, and three high-altitude tests over the Atlantic Ocean during Operation ARGUS in 1958. These operations are collectively referred to as the “oceanic series.” The first nuclear test series was Operation CROSSROADS, conducted at Bikini Atoll in 1946. The following year, the Atomic Energy Commission established the Pacific Proving Ground (PPG) in the region of the Marshall Islands (Figure 2). The PPG initially consisted of the areas around Bikini and Enewetak Atolls (Figure 3 and Figure 4). It was subsequently renamed the Enewetak Proving Ground in 1958 and expanded to include Johnston and Christmas Islands (Figure 2). To

avoid confusion in this report, the acronym “PPG” is used to designate this test area, regardless of time, and is considered to apply retroactively to CROSSROADS.

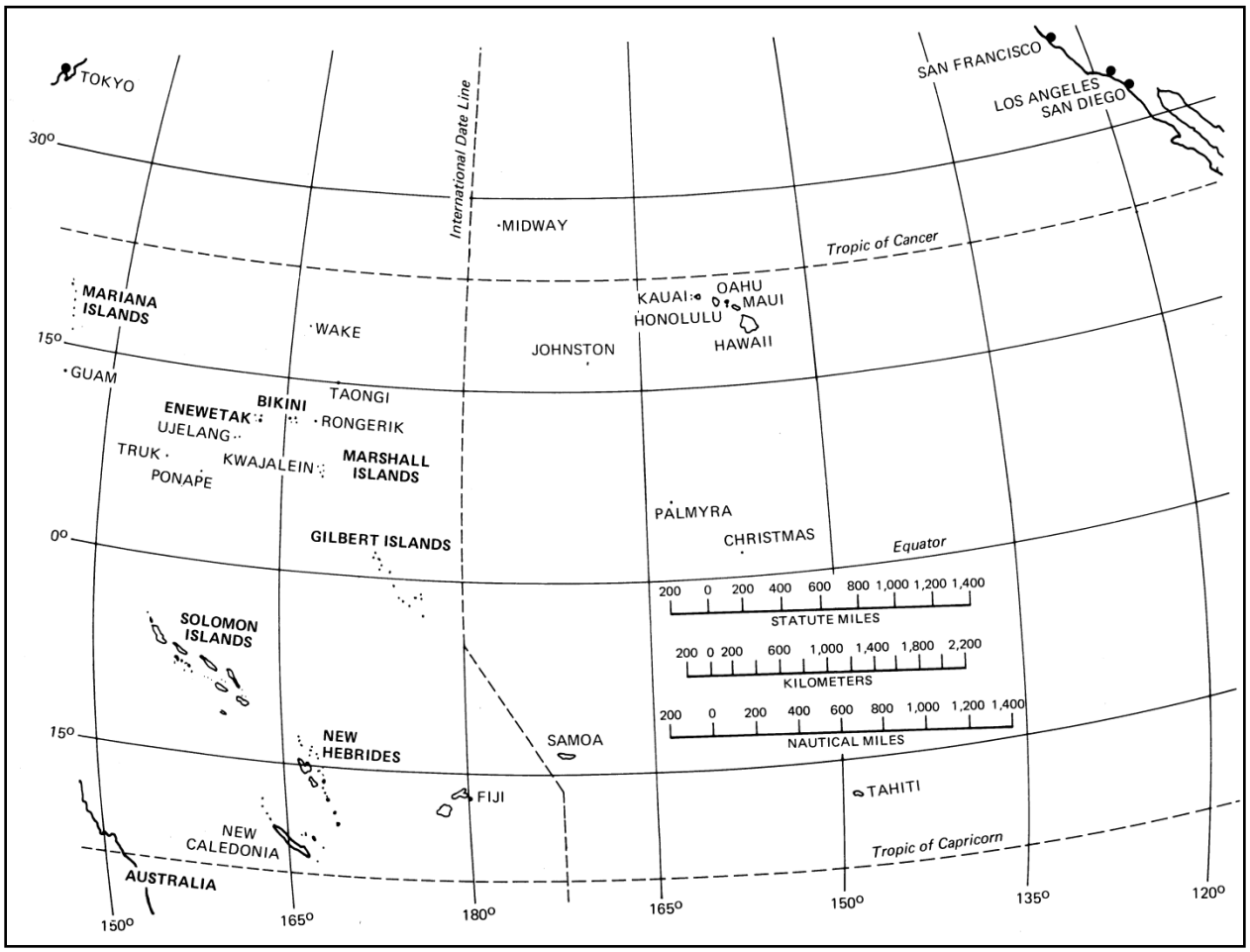

Figure 2. Map of the Pacific Proving Ground

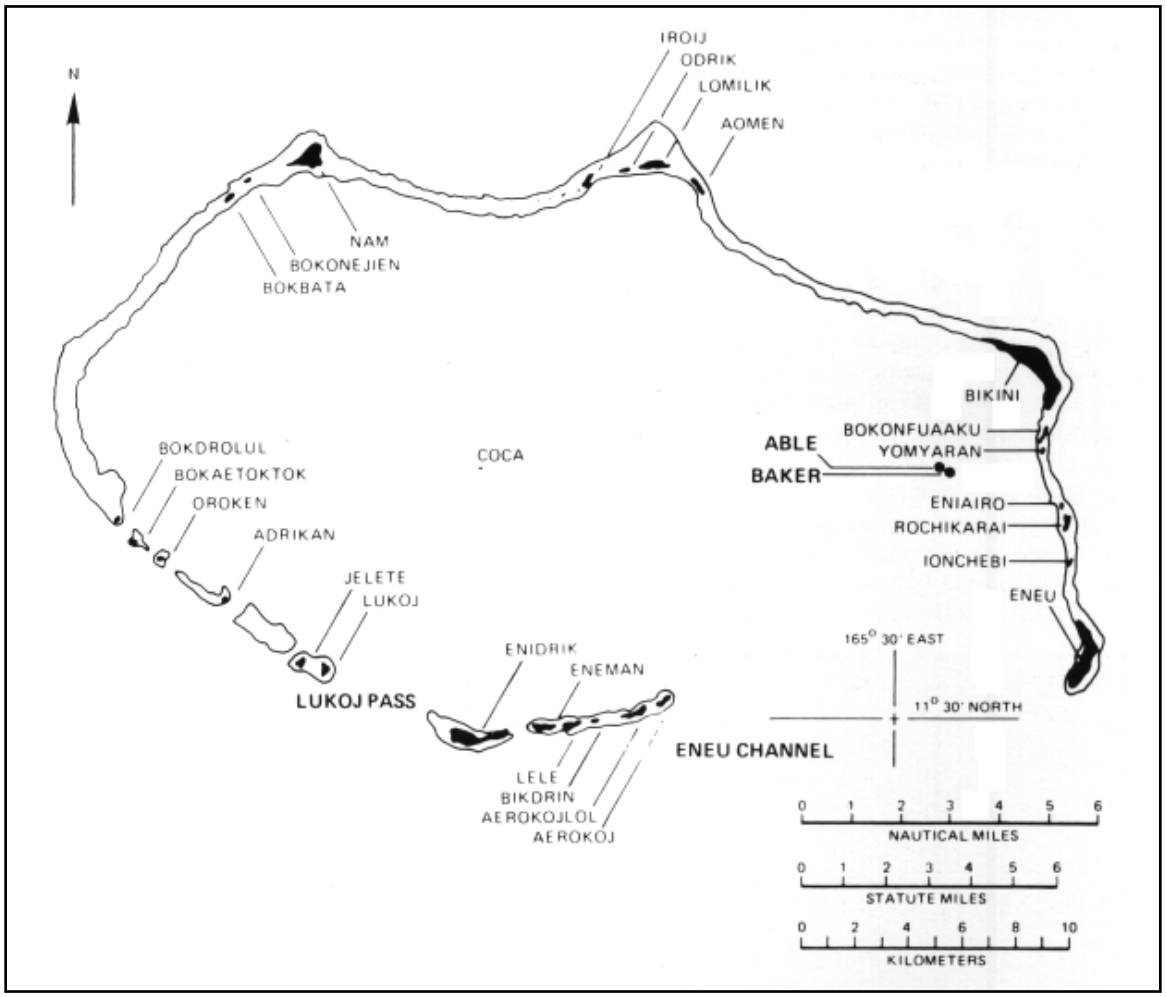

Figure 3. Map of Bikini Atoll during Operation CROSSROADS

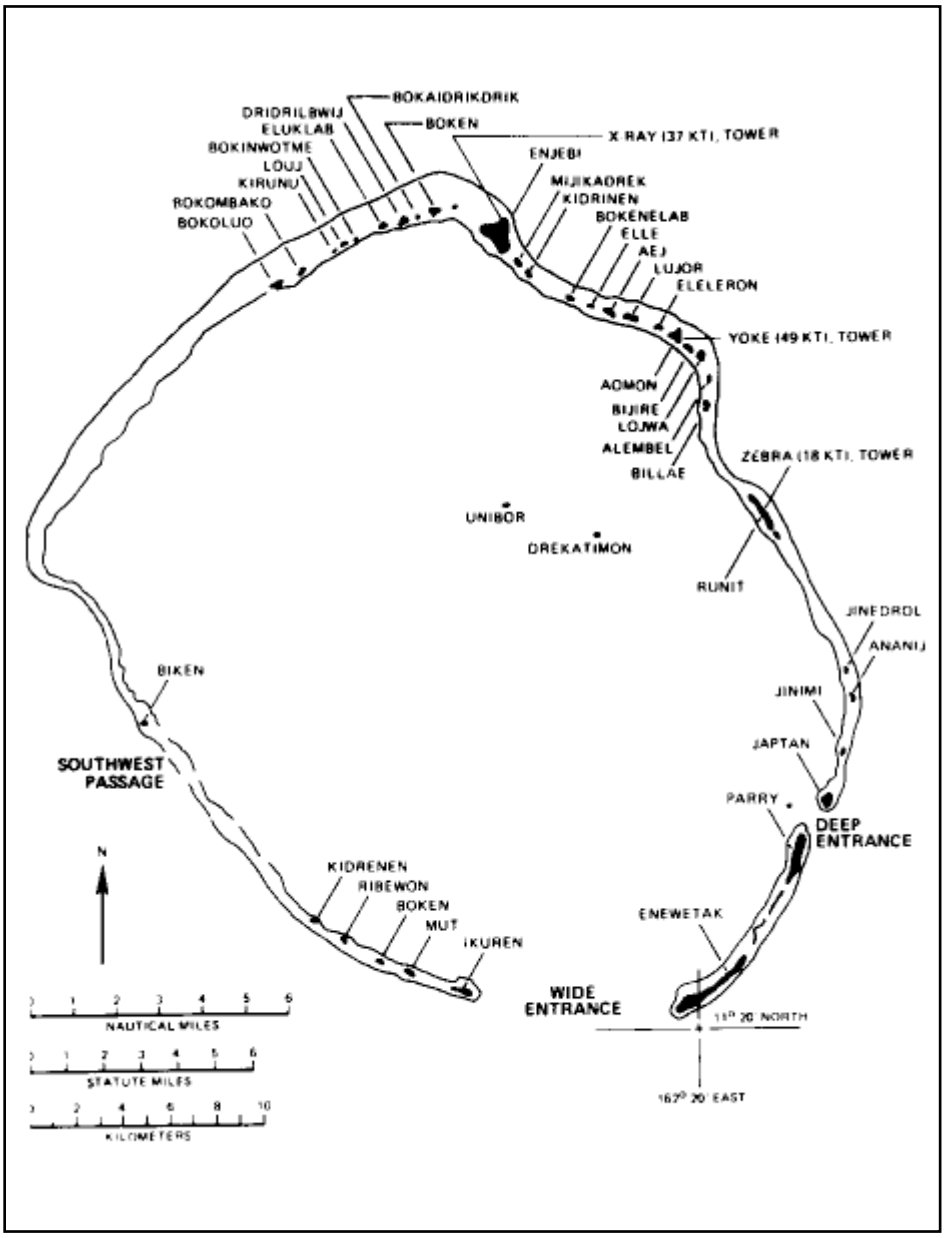

Figure 4. Map of Enewetak Atoll during Operation SANDSTONE

Seven operations were conducted in the PPG after Operation CROSSROADS: SANDSTONE (1948), GREENHOUSE (1951), IVY (1952), CASTLE (1954), REDWING (1956), HARDTACK I (1958), and DOMINIC I (1962). Each was supported by personnel stationed on either ships (generally U.S. Navy ships), or on various "residence" islands. EPGs for participants of the PPG operations are typically broken out by operation and by residence base (e.g., GREENHOUSE Land-Based Personnel and HARDTACK I Ship-Based Personnel). As needed, categories are subdivided to allow greater specificity of EPGs (e.g., the CROSSROADS

Support Ship-Based Personnel and the CROSSROADS Target Ship-Based Personnel are distinct EPGs, and the HARDTACK I Ship-Based Personnel EPG is separate from the HARDTACK I non-Exposed Ship-Based Personnel EPG). The EPGs of island-based and ship-based participants are discussed in the next two sub-sections, respectively.

The remaining Pacific operation, Operation WIGWAM, was conducted in 1955 approximately 500 miles southwest of San Diego, CA, and thus outside the PPG. All the ship-based personnel at Operation WIGWAM are included in a single EPG.

Some exposure scenarios involve activities that occurred after test operations had been formally terminated. Separate participant groups have been formulated in these cases and are addressed in the final sub-section.

4.1.1 Land-Based Personnel

Large numbers of operational and support personnel were billeted on "residence islands" during most oceanic series. These residence islands typically included Enewetak, Parry, and Japtan Islands of Enewetak Atoll and Eneu Island of Bikini Atoll, but varied somewhat from series to series. The residence islands for each operation are listed in the EPG Compendium (DTRA, 2011). The land-based personnel on the residence islands in the PPG during an oceanic test operation constitute a viable group for expedited assessment for the reasons discussed below.

First, land-based personnel were stable and remained nearly stationary throughout an operation. They were stable because relatively few people transferred to or from the resident units during a test operation. They were stationary because most land-based personnel had little opportunity or incentive to participate in excursions away from the residence islands.

Second, the radiation environments were similar for all groups of the land-based personnel. All residence islands were at distances from the detonation sites that precluded exposures to initial gamma and neutron radiations. Residual radiation from fallout on the residence islands was the primary source of both external and internal exposures for all land-based personnel. Nearly all fallout events on these islands occurred 10 or more hours after the times of detonation of the fallout-producing shots. At these times, the descending and deposited material to which land-based personnel were exposed consisted mostly of fine, inhalable particulates. The fallout deposition was fairly uniform over the inhabited area because by the time fallout arrived, the breadth of the radioactive fallout cloud was large compared to the dimensions of a residence island or the distance between such islands. As a result, most land-based personnel at a specific operation are likely to have encountered similar radiation exposure rates and consequently, accrued similar external doses.

Third, the pathways for internal exposures were common to all land-based personnel. These were inhalation of descending fallout, inhalation of resuspended fallout, and incidental ingestion of contaminated soil and dust. Because the sizes of the descending particles were generally small, all land-based residents who were outside during a fallout event inhaled the fallout with comparable efficiency. In addition, the fallout episodes on the residence islands were radiologically small enough that precautions were not taken to limit the exposure of the land-

based personnel to the descending fallout. Since the terrain and climate were generally similar throughout the occupied area, the resuspension of fallout particles from the ground and other surfaces would have been comparable. Thus, internal doses are expected to have been comparable across the population of land-based personnel present on the residence islands of the PPG.

4.1.2 Ship-Based Personnel

For reasons similar to those listed for land-based PPG participants, the ship-based personnel that supported oceanic testing also qualify as viable EPGs. Crews were stable and spatially constrained throughout an operation. Relatively few personnel transferred to or from a ship's crew during an operation, and there were limited opportunities for crew members to participate in off-ship excursions. When substantive transfers occurred, as for the crews of targets ships at Operation CROSSROADS, the impact of such transfers on the doses was taken into consideration for those specific EPGs.

The sources of exposure were similar across most ships in a given operation. All support ships were at distances from the detonations that precluded exposures of ship-based personnel to initial gamma and neutron radiations. The primary source of both internal and external exposure for most ship-based personnel was residual fallout on the deck. Secondary sources of external exposure included contaminated lagoon water and accumulations of fallout on the hulls and in the saltwater piping systems of the ships themselves. Similar to the case of the land-based groups, fallout events involving ship-based personnel generally occurred 10 or more hours after the time of detonation. Consequently, the deposited material to which shipboard personnel were exposed consisted mostly of fine particulates.

Most ships participating in test operations were equipped with automated washdown systems that were fairly effective at removing fallout particles from topside locations, thereby limiting exposures to the crews. Those ships without automated systems usually resorted to manual methods to remove deposited material. Thus, the mitigating effects of decontamination are another common feature among support ships.

Most crew members of a given ship are expected to have received generally comparable external and internal doses since the radiation environment experienced by individuals on that ship were similar. The consistency of external doses aboard individual ships is confirmed from film badge records. However, because a ship's inherent mobility allowed the fleet of support ships to be widely dispersed during some fallout events, the amount of fallout deposition on these vessels varied significantly. This variability was probably reduced somewhat by decontamination—the more heavily contaminated ships are likely to have expended more effort in decontamination than marginally contaminated vessels. Nevertheless, the ship-to-ship variation in mean external dose is noticeably larger than the analogous variation seen among land-based units. One method of mitigating this condition for the purpose of expediting cases is to divide the population of ships into two or more tiers based on the crews' average external doses, and treating each tier as a separate group. This is the case for ship-based personnel at Operation CASTLE, which has separate EPGs for "high-dose" and "low-dose" ships. The low-

dose EPG includes ships with resulting external and internal doses that produce a PC of less than 40 percentfor all organs except thyroid, liver, gall bladder, and bile duct. These four organs are associated with low screening doses that are easily exceeded when attempting to make as many Operation CASTLE ships as possible eligible for expedited processing for all other organs. The selection of the two sets of ships was done primarily based on published external residual radiation doses and fine-tuned through an iterative process.

A major pathway for internal exposure—the inhalation of resuspended fallout—was common to most shipboard personnel. Since the surface characteristics of weather decks and decontamination procedures were similar for most ship types, the subsequent resuspension of residual fallout particles would have been comparable. On the other hand, most ship-based personnel were not affected by descending fallout except for those few with duties that required their presence on weather decks during episodes of fallout. Material conditions (i.e., steps taken to increase the "tightness" of a ship) were set based on radiological safety considerations and stringently applied to prohibit non-essential personnel from being topside during fallout events. Personnel whose duties or temporary assignments required them to remain topside during documented or presumed episodes of descending fallout are classified as exclusions.

4.1.3 Other Categories of Oceanic Series Personnel

Other groupings of personnel who performed missions and/or conducted activities related to nuclear testing in the PPG also satisfy the criteria for expedited processing. Typically these groups are small, their exposure scenarios are unique, and the periods of their performance extended beyond the end of formal operations. These conditions inhibit the inclusion of these groups into the EPG categories discussed previously. These groups include the following:

- Inter-Operational Participants at Enewetak Atoll. Personnel were assigned to Enewetak Atoll following Operations SANDSTONE, GREENHOUSE, IVY, CASTLE, REDWING, and HARDTACK I. These participants served as a garrison force between operations to maintain the facilities on Enewetak Atoll and to prepare for the next operation. They generally departed the test site before any nuclear detonations of the next operation were conducted. The nature and timing of these missions are unique compared to Enewetak Atoll residents during test operations.

- USS BRUSH Crew (February 25–27, 1947). The unique environment to which members of the BRUSH crew were exposed involves the handling and storage of contaminated souvenirs scavenged at Kwajalein from ships that had formerly served as target ships at CROSSROADS. There is little commonality between the exposure scenarios of this group and the crews of support and target ships that are the subject of Operation CROSSROADS EPGs.

- Bikini Resurveys (July–August, 1947). This small group performed or supported scientific activities (e.g., collecting fish, water, and soil samples in July and August 1947 at Bikini). The nature and timing of these activities are unique compared to those addressed in the more standard EPGs of ship-based and land-based personnel.

- Operations ARGUS, DOMINIC I, HARDTACK I non-exposed ships. Personnel in these three groups were assigned to ships that participated in high-altitude detonations that did not result in any doses from initial neutron or gamma radiation due to the distances between their locations and the detonations. In addition, no descending or residual fallout occurred due to the altitude and separation from the detonations.

The USS BRUSH crew and the Bikini resurvey personnel are not considered participants as defined by the Department of Veterans Affairs in Title 38, Code of Federal Regulations (38 CFR 3.309); these VA regulations supply the criteria that the NTPR Program applies in determining whether or not an individual is confirmed as a U.S. atmospheric nuclear test participant. However, these groups' potentials for radiation exposure are being addressed in this report. (Note: some Bikini Resurvey personnel took part in eligible activities in other atmospheric tests and are therefore considered participants for those.)

4.2 Participants in the NTS/CONUS Series

Atmospheric weapons tests in the continental United States (CONUS) were conducted almost exclusively at the NTS[2, 3] between 1951 and 1962 (USDOE, 2000). The personnel included in the NTS EPGs discussed in this report are limited to the military participants that formed a large portion of the roughly 75,000 Department of Defense (DoD) personnel who took part in those NTS detonations. Military personnel took part in three general types of activities during the NTS test series: scientific experiments, military technical and training projects, and support services. Troops from the latter two categories of participation compose the NTS EPGs.

Most NTS participants can be included in one of the four groupings described in this section. Grouping of participants for the purpose of expedited processing was based primarily on the type and extent of activities conducted in the forward NTS test areas, where most of the radiation doses for EPG members were received. Members of all NTS EPGs also received a dose from fallout contamination at the locations where they were housed. As used here, "forward NTS test areas" refers to areas north of News Nob near the Control Point and the Frenchman Flat area to the east of the Mercury Highway as illustrated in Figure 5. The NTS EPGs were grouped based on the overall similarity of activities, radiation environments encountered, and magnitude of the doses received, using the criteria described in Section 3 of this report. Details of each NTS EPG are contained in the EPG Compendium (DTRA, 2011), which is a companion document to this report. The rationale for grouping the cohorts in each of the proposed NTS EPGs is discussed in the following sections.

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[2] The Nevada Test Site was known as the Nevada Proving Ground prior to 1955. This report uses only the name Nevada Test Site (NTS) for simplicity.

[3] One atmospheric detonation (TRINITY) was conducted at Alamogordo, New Mexico, in 1945.

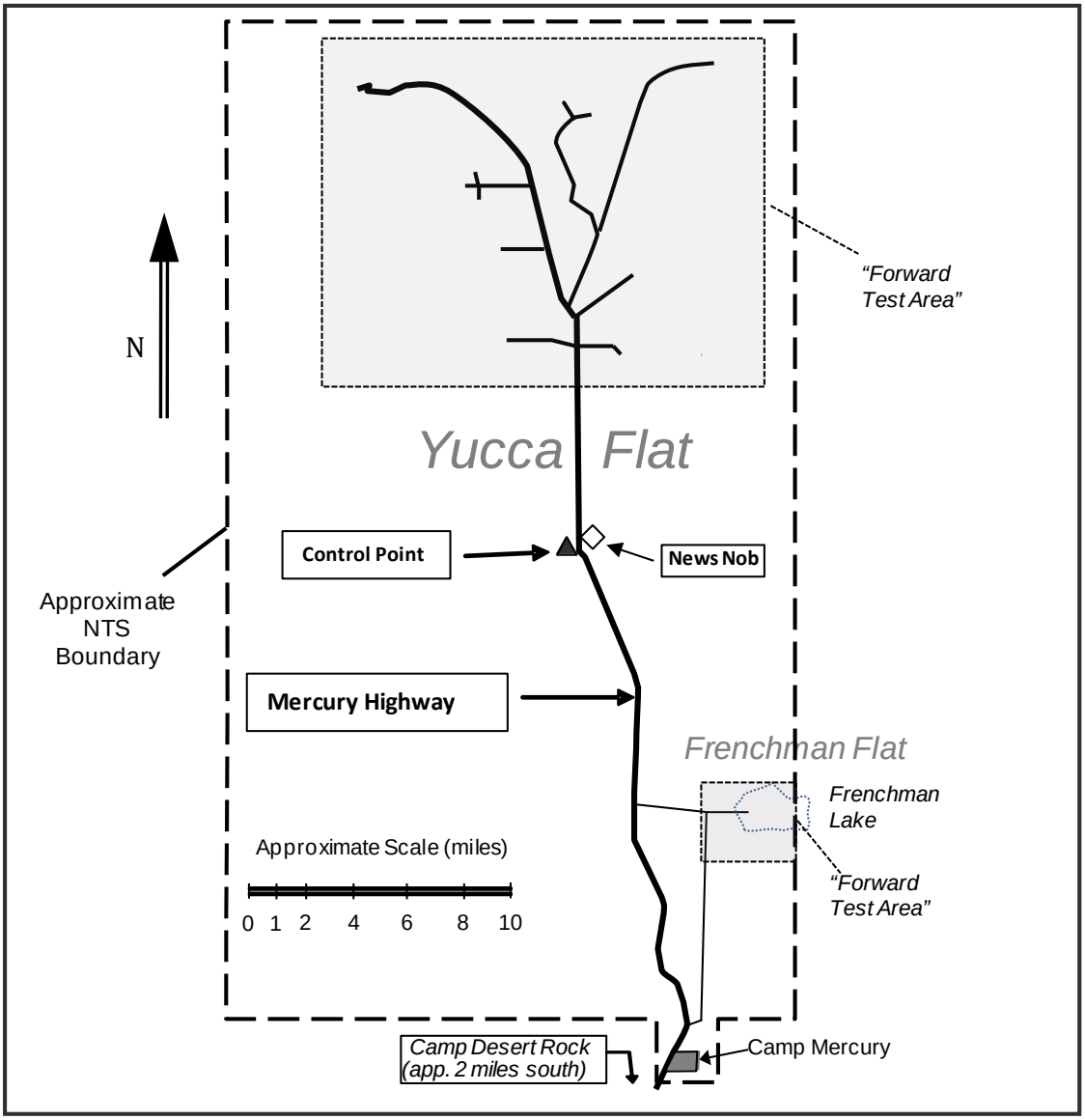

Figure 5. Schematic of NTS 1951-1962 Indicating Approximate Locations of Forward Test Areas

4.2.1 NTS Participants with Maneuver or Observer Activity

During all NTS test series, members of all services participated in official observer or tactical troop maneuver activities (DTRA, 2008, Appendix C-2 to C-9). Most of these personnel were Exercise Desert Rock (EDR) "service" troops who traveled from their home stations to Camp Desert Rock (CDR), located immediately south of the NTS, specifically to participate in an observer or maneuver training exercise. The activities of these service troops were usually limited to participation associated with a single nuclear test. Other observer and maneuver

troops consisted of Camp Mercury and CDR support troops (i.e., troops who provided support functions for one of the camps or in support of Atomic Energy Commission (AEC) or EDR activities). Participants with activities at multiple operations are excluded from automatic expedited processing and their cases are referred for further review and assessment.

One specific CDR support group has been evaluated and is included in the NTS Participants with Maneuver or Observer Activity EPG: personnel in the 505th Military Police Battalion (505 MPB) that participated during Operation UPSHOT-KNOTHOLE (1953) or Operation TEAPOT (1955). Personnel from this unit provided routine military police duties at CDR and traffic control for military vehicular movement in forward areas of the NTS during EDR activities. They were exposed to residual radiation in NTS forward test areas during rehearsals and shot-day activities (Frank, 1982). As CDR support personnel, these troops also participated in a maneuver and may have been observers at a detonation (Edwards et al., 1985). Activities, exposure sources, and dose ranges for 505 MPB personnel were evaluated separately and were found to be comparable to those of the NTS maneuver and observer troops discussed in this section and in the EPG Compendium (DTRA, 2011). Therefore, personnel in the 505 MPB who participated during Operation UPSHOT-KNOTHOLE or Operation TEAPOT are included in this grouping of NTS participants with maneuver or observer activity.

Another specific group that has been evaluated and is also included in the NTS Participants with Maneuver or Observer Activity EPG is Task Force BIG BANG (TFBB) personnel, who participated during Operation PLUMBBOB (Goetz et al., 1980). This task force was a provisional company from the 82nd Airborne Division that participated in rehearsals and conducted an exercise at the NTS in August and early September 1957. In general, TFBB personnel conducted activities similar to those of the NTS maneuver troops. They traveled from their home station to CDR specifically to participate in a maneuver exercise, and spent a period of 2 to 3 weeks at CDR. Their activities included training at CDR and rehearsals and testing in the forward test area. They observed one or more shots from News Nob, observed Shot GALILEO from Mercury Highway, and conducted specific military tasks following the GALILEO detonation. During their forward area activities, TFBB personnel were exposed to residual radiation from several earlier Operation PLUMBBOB shots. Their activities consisted primarily of walking or driving over open terrain, but also included crawling over terrain, during which they were exposed to resuspended fallout. Activities, exposure sources, and dose ranges for TFBB personnel were evaluated separately, and were found to be comparable to those of the NTS maneuver and observer troops discussed in this section and in the EPG Compendium (DTRA, 2011). Therefore personnel in TFBB are included in this grouping of participants with maneuver or observer activity.

The majority of the maneuver and observer cohorts who participated over the years of the NTS test series can be consolidated into a single group for the purpose of expedited processing. This determination is based on the similarity in activities, exposure sources, and exposure pathways of participants, described as follows:

- Housing, orientation and training at CDR or Camp Mercury for a period of about one week to several months, where there was the potential for exposure to no more than one fallout event.

- Short periods of time (typically several hours) in NTS forward areas, conducting activities consisting primarily of walking or driving over open terrain.
- No activities with potential high exposure such as radiation safety, retrieval of scientific instruments, excessive digging, or operation of heavy equipment in contaminated areas.
- Comparable external exposures to deposited fallout or radionuclides in the soil that are produced by neutron activation from recent detonations at exposure rates limited by comparable exposure guidelines.
- Internal exposures from inhalation of descending fallout, inhalation of fallout resuspended by typical troop activities (walking or driving over open terrain), and inhalation of fallout resuspended by detonation effects.
- Sources of exposures only from initial radiation and residual radiation from fallout or radionuclides in the soil that are produced by neutron activation.

Although participants did not experience exactly the same levels of exposure nor the same specific types of exposure (e.g., inhalation of fallout resuspended by detonation effects), NTS troops participating as maneuver or observer troops generally conducted similar activities that resulted in comparable exposure to residual radiation. Furthermore, the sources of residual radiation resulting in exposure of these troops were generally similar in type and duration.

4.2.2 NTS Participants with no Forward Area Activities

Troops supporting AEC/DoD, EDR, and Air Force Special Weapons Center activities at NTS tests from 1951 to 1962 worked and lived at Camp Mercury, CDR, Indian Springs Air Force Base (AFB), or Nellis AFB. These support troops were assigned to one of these locations typically throughout a series (as long as five months in the case of Operation PLUMBBOB), although not all remained for the entire period. (DTRA, 2008, Appendices C-2 to C-9)

NTS support personnel in this grouping are those who completed their assignments without entering the NTS forward. For these personnel, doses received resulted from exposure to fallout deposited at their housing/work location. Because fallout events and the types of activities resulting in exposures are comparable, the cohorts composing this overall group consist of all the support troops at billet locations mentioned above during all NTS test series from 1951 to 1962 that did not carry out activities in the forward areas. These cohorts can be consolidated into a single exposure group for the purpose of expedited processing based on the following common features of activities and exposure sources and pathways shared by the support troops in this grouping:

- Activities limited to general living and support tasks at billet location for a period of up to a few months where there was the potential for exposure to no more than three fallout events. These troops did not enter into any NTS forward areas, meaning that external exposure was from deposited fallout from recent detonations at the participant's housing location.

- Comparable external doses from residual radiation.
- Internal exposure to descending fallout and recently-deposited fallout resuspended by typical troop activities such as walking or driving over roadways or graded ground.
- Sources of exposures only from fallout or radionuclides in the soil that are produced by neutron activation.

The above list demonstrates that NTS support troops who did not enter any NTS forward areas conducted similar activities that resulted in comparable exposure to residual radiation and that the sources of residual radiation resulting in exposure of these troops were similar in type and duration.

4.2.3 Task Force WARRIOR

Task Force WARRIOR (TFW) was a reinforced infantry company from the 4th Infantry Division that was present at the NTS during Operation PLUMBBOB. This group participated in rehearsals, prepared defensive positions, and conducted an exercise at the NTS in August and early September 1957 (DTRA, 2008, Appendix C-7). The task force was excluded from the NTS Maneuver and Observer grouping because of TFW exposures to multiple previous fallout events that required further evaluation, and because questions have been raised regarding the shot-day exposure of this group (NAS/NRC, 2003).

In general, TFW personnel conducted activities similar to those of the other NTS maneuver troops: they traveled from their home station to CDR specifically to participate in a maneuver exercise. Their primary activity was conducted after observing Shot SMOKY. There are no clearly defined cohorts for TFW, and thus the high-dose cohort analysis for this group is based on the assumption that certain participants conducted a set of activities known to have been performed by specific TFW personnel. There are certain activities that not all subgroups of TFW personnel conducted; however, the makeup of performing subgroups and the extent to which TFW personnel were in multiple subgroups are unknown. Although not all TFW members participated in exactly the same manner, activities that may have resulted in exposures to residual radiation and the sources of such radiation were similar. These are described as follows:

- Housing, orientation, and training at CDR for a single period of 4 weeks.
- Several hours in the NTS forward area, conducting activities consisting primarily of walking or driving over open terrain.
- External exposure to deposited fallout and radionuclides in the soil that are produced by neutron activation from recent detonations at exposure rates limited by exposure guidelines.
- Comparable external doses from residual radiation.

- Internal exposure to recent fallout resuspended by typical troop activities such as walking or driving over open terrain.
- Possible internal exposure to recent fallout resuspended by digging.
- Internal exposure to a single descending fallout event at CDR, and for some members of the task force to descending SMOKY fallout in the shot area.
- Sources of exposures only from initial radiation and residual radiation from fallout or radionuclides in the soil that are produced by neutron activation.

The troops of TFW conducted similar activities that resulted in comparable exposure to residual radiation, and the sources of residual radiation resulting in exposure of these troops were similar in type and duration. Therefore, it is reasonable to include all TFW personnel in a single EPG for the purpose of expediting processing.

4.2.4 Second Marine Corps Provisional Atomic Exercise Brigade

The 2nd Marine Corps Provisional Atomic Exercise Brigade (2MCPAEB) was a provisional unit comprising two Marine battalions with four companies each, a Marine air group comprising five squadrons, and a Headquarters unit. This unit of approximately 2,150 personnel conducted the largest DoD activity at Shot BADGER during Operation UPSHOT-KNOTHOLE in 1953 (DTRA, 2008, Appendix C-5). The 2MCPAEB was excluded from the NTS Maneuver and Observer grouping because their activities resulted in higher exposures than those in the NTS Observer and Maneuver group.

In general, 2MCPAEB personnel conducted activities similar to those of other NTS maneuver troops. They traveled from their home stations to CDR specifically to participate in a maneuver exercise. While some of the 2MCPAEB troops observed one or two shots from News Nob before the maneuver, the primary activities of this brigade consisted of a rehearsal and two days later the maneuver in conjunction with Shot BADGER (DTRA, 2008; Frank et al., 1982). The 2MCPAEB group comprised several cohorts; each was a cohesive unit, and all members conducted similar activities. Representative film badge records are available for all cohorts (DTRA, 2010c), and the highest-dose cohort determination is based on a comparison of the average film badge readings of the cohorts. Differences in exposures between the 2MCPAEB cohorts exist. However, activities that may have resulted in exposures to residual radiation and the sources of such radiation were comparable, as described below:

- Housing, orientation, and training at CDR for a single period of about 2 weeks.
- Two periods of time in NTS forward areas with activities consisting primarily of walking or driving over open terrain; some personnel were transported by helicopters.
- Comparable external exposure to deposited fallout from recent detonations at exposure rates limited by the exposure guidelines.

- Internal exposure to recent fallout resuspended by typical troop activities, such as walking or driving over open terrain, and by helicopter downwash during limited loading/unloading activities for some troops.
- Possible internal exposure to aged fallout resuspended by detonation effects in the forward area.
- Sources of exposures only from initial radiation and residual radiation from fallout or radionuclides in the soil that are produced by neutron activation.

The troops of the 2MCPAEB conducted similar activities that resulted in comparable exposure to residual radiation, and the sources of residual radiation resulting in exposure of these troops were similar in type and duration. Therefore, it is reasonable to include all 2MCPAEB personnel into a single EPG for the purpose of expedited processing.

5.

Radiation Dose Assessment Results for Expedited Processing

During the developmental phase of the study, a total of 32 EPGs were identified that collectively address the majority of the PPG and NTS participants. Among these, the three EPGs for Operation ARGUS, Operation DOMINIC I, and Operation HARDTACK I non-exposed ships pertain to cohorts that had no potential for exposure to radiation during their participation. The 32 EPGs are listed in Appendix B and assessed individually in the accompanying EPG Compendium (DTRA, 2011). As important as identifying the participants that are covered by these EPGs is the explicit identification of those participants whose possible exposure scenarios are too complex or not sufficiently characterized to include in a general expedited process. The units and types of participant activities that are not recommended for expedited processing (i.e., exclusions) are identified in the EPG Compendium. To process an excluded case, further review and a more comprehensive RDA would be required.

This section summarizes the EPG dose assessment results and discusses the applicability of expedited processing for the 32 EPGs based on the suitability test proposed in Section 3.

5.1 Development of Expedited Processing Groups

The details of the dose assessments for the 32 EPGs are included in the EPG Compendium (DTRA, 2011). Each EPG dose assessment report specifies the composition of the EPG and provides detailed descriptions of the scenarios of exposure, exposure pathways, maximizing assumptions, and the dose parameter values employed in the dose calculations. In addition, the EPG Compendium identifies units, groups, individuals, and activities for which expedited processing methods are not recommended.

Similarity of the exposure scenarios for many of the NTS participants allowed their consolidation into more broadly defined exposure groups consistent with the objectives of the study. Consequently, the 32 EPGs consist of only four EPGs for the NTS and 28 EPGs for the PPG. The PPG EPGs are further subdivided into 22 EPGs representing participation during actual test operations and six EPGs covering individuals whose activities occurred in time periods after or between test operations. The PPG EPGs are subdivided into land-based, ship-based, and other groups consisting of cohorts with unique exposure circumstances, as discussed in Section 4.

5.2 Dose Assessment Results

Scenario-based external and internal doses were calculated for each EPG based on the methodology described in Section 3. These doses and their corresponding upper bounds are recommended for use in expedited processing of most NTPR cases.

5.2.1 Summary of EPG Doses

The EPG doses consist of high-sided estimates calculated using exposure scenarios and input parameter values that maximize each dose component. The EPG doses are estimated for external gamma radiation, internal alpha radiation, and internal beta-plus-gamma radiation for the 20 relevant NTPR Standard Organs; ovaries, uterus, and skin are not included. The resulting upper-bound doses are generated from the EPG doses by applying DTRA-approved uncertainty factors, which are detailed in the EPG Compendium (DTRA, 2011). The EPG doses were calculated to meet the criteria recommended by the VBDR that these doses be based on worst-case parameter values and assumptions, and that their upper bounds be higher than any realistically calculated veteran's upper-bound doses. Across all EPGs, the estimated upper-bound EPG external doses range from less than 0.1 to about 23 rem. Similar but wider ranges are observed for internal organ doses (DTRA, 2011). The EPG external doses, the external and internal upper bound doses, and the total doses for NTS, PPG-land based, and PPG ship-based personnel are provided in Table 4 to Table 7. The total (or the overall) upper-bound dose is the sum of the upper-bound external gamma dose and upper-bound alpha and beta-plus-gamma internal doses.

5.2.2 Alpha Doses for the ET Region and Lungs

The doses due to alpha particles from inhalation of isotopes of the elements uranium, neptunium, plutonium, americium and curium were calculated assuming absorption type M[4]. This assumption was based on a determination that the oxides of these materials in fallout could be considered to have an indeterminate solubility and is the standard for the NTPR program (DTRA, 2010a). During the course of this study, reviewers noted that this assumption tended to maximize the doses from alpha particles to all FIIDOS organs except the ET region and lung, for which absorption type S results in higher doses.

[4] Absorption type is a term defined in ICRP (1994) that characterizes the solubility of deposited radioactive materials in human organs and tissues. Three absorption types are used according to whether the absorption to blood is considered to be fast (F), moderate (M), or slow (S).

Table 4. Estimated Radiation Doses (rem) for Ship-Based Personnel at the Pacific Proving Ground*

EPG Name		Radiation Type†	Adrenals	Bone Surface	Brain	Breast	Stomach wall	Small Intestine wall	Upper Large Intestine Wall	Lower Large Intestine Wall	Kidneys	Liver	Extra-Thoracic Region	Lung	Muscle	Pancreas	Red Marrow	Spleen	Testes	Thymus	Thyroid	Urinary Bladder Wall
XRDS Target Ships		UB α	0.09	47	0.09	0.09	0.09	0.09	0.09	0.09	0.2	11	0.5	1	0.09	0.09	3	0.09	0.7	0.09	0.09	0.09
Ext Dose	Upper Bound	UB β+γ	0.3	3	0.2	0.2	0.9	2	8	19	0.4	0.7	9	19	0.3	0.3	0.9	0.3	0.2	0.3	45	0.6
3	9	total	9	58	9	9	10	11	17	28	10	20	19	28	9	9	12	9	10	9	53	10
XRDS Support Ships		UB α	0.003	2	0.003	0.003	0.003	0.003	0.003	0.003	0.006	0.3	0.02	0.03	0.003	0.003	0.07	0.003	0.02	0.003	0.003	0.003
Ext Dose	Upper Bound	UB β+γ	0.09	0.005	0.006	0.04	0.08	0.4	0.9	0.02	0.03	0.2	0.4	0.009	0.01	0.04	0.008	0.007	0.007	2	0.03	0.03
3	9	total	10	9	9	9	9	9	10	9	9	9	9	9	9	9	9	9	9	10	9	10
USS BRUSH		UB α	0.09	51	0.09	0.09	0.1	0.1	0.2	0.2	0.3	11	0.5	1	0.09	0.09	3	0.09	0.7	0.09	0.09	0.09
Ext Dose	Upper Bound	UB β+γ	0.3	3	0.2	0.2	0.5	1	5	13	0.3	0.6	0.5	4	0.2	0.3	0.8	0.2	0.2	0.2	0.2	0.3
0.08	0.3	total	0.6	53	0.5	0.5	0.9	2	5	13	0.7	12	2	5	0.6	0.6	4	0.6	2	0.6	0.6	0.6
SANDSTONE Ships		UB α	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	<0.001	0.002	<0.001	<0.001	<0.001	0.002	0.006	0.02	<0.001	<0.001	0.02	0.03	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	<0.001
0.09	0.3	total	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
GREENHOUSE Ships		UB α	<0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	0.001	0.003	<0.001	<0.001	0.005	<0.001	0.002	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	0.02	0.2	0.01	0.02	0.1	0.2	0.7	2	0.02	0.03	2	3	0.02	0.02	0.06	0.02	0.009	0.02	3	0.06
3	7	total	7	7	7	7	7	7	7	8	7	7	9	9	7	7	7	7	7	7	9	7
IVY Ships		UB α	<0.001	0.03	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	<0.001	0.02	<0.001	<0.001	0.002	0.004	0.02	0.04	<0.001	0.004	0.05	0.08	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.05	<0.001
0.07	0.2	total	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
CASTLE Ships (High)		UB α	0.009	5	0.009	0.009	0.009	0.009	0.009	0.009	0.03	1	0.05	0.2	0.009	0.009	0.3	0.009	0.07	0.009	0.009	0.009
Ext Dose	Upper Bound	UB β+γ	0.2	5	0.08	0.2	1	2	7	13	0.3	0.8	21	24	0.2	0.2	0.5	0.2	0.2	0.2	16	0.5
8	23	total	23	32	23	23	24	25	30	36	23	25	43	47	23	23	24	23	23	23	38	23
CASTLE Ships (Low)		UB α	0.02	7	0.02	0.02	0.02	0.02	0.02	0.02	0.03	2	0.07	0.2	0.02	0.02	0.4	0.02	0.1	0.02	0.02	0.02
Ext Dose	Upper Bound	UB β+γ	0.08	5	0.04	0.07	0.4	0.7	3	6	0.2	0.9	8	12	0.07	0.08	0.4	0.07	0.08	0.09	7	0.2
4	12	total	12	22	12	12	12	13	15	17	12	14	20	23	12	12	13	12	12	12	18	12

Table 4. Estimated Radiation Dose (rem) for Ship-Based Personnel at the Pacific Proving Ground* (cont.)

EPG Name		Radiation Type†	Adrenals	Bone Surface	Brain	Breast	Stomach wall	Small Intestine wall	Upper Large Intestine Wall	Lower Large Intestine Wall	Kidneys	Liver	Extra-Thoracic Region	Lung	Muscle	Pancreas	Red Marrow	Spleen	Testes	Thymus	Thyroid	Urinary Bladder Wall
WIGWAM Ships		UB α	<0.001	0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	0.002	0.003	<0.001	<0.001	0.006	<0.001	0.002	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	0.007	0.05	0.004	0.006	0.04	0.07	0.3	0.5	0.007	0.009	0.8	0.7	0.006	0.007	0.02	0.006	0.004	0.007	1	0.03
0.3	0.6	total	0.6	0.8	0.6	0.6	0.6	0.7	0.9	1	0.6	0.6	2	2	0.6	0.6	0.6	0.6	0.6	0.6	2	0.6
REDWING Ships		UB α	<0.001	0.09	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	0.002	<0.001	<0.001	0.005	<0.001	0.002	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	0.01	0.1	0.005	0.008	0.05	0.09	0.4	0.8	0.02	0.02	2	2	0.009	0.01	0.03	0.008	0.005	0.02	2	0.03
3	7	total	7	7	7	7	7	7	7	7	7	7	8	8	7	7	7	7	7	7	8	7
HARDTACK I Ships		UB α	0.003	2	0.003	0.003	0.003	0.003	0.003	0.003	0.007	0.4	0.02	0.04	0.003	0.003	0.08	0.003	0.03	0.003	0.003	0.003
Ext Dose	Upper Bound	UB β+γ	0.03	0.4	0.02	0.03	0.08	0.2	0.8	2	0.2	0.09	3	3	0.03	0.03	0.09	0.2	0.02	0.03	3	0.2
2	6	total	6	8	6	6	6	6	7	8	6	7	9	9	6	6	6	6	6	6	9	6
HARDTACK I Non-Exposed Ships		UB α	No Potential for Exposure																			
Upper Bound		UB β+γ	No Potential for Exposure																			
NPE+		total	No Potential for Exposure																			
ARGUS Ships		UB α	No Potential for Exposure																			
Ext Dose	Upper Bound	UB β+γ	No Potential for Exposure																			
NPE+	NPE	total	No Potential for Exposure																			
DOMINIC I Ships		UB α	No Potential for Exposure																			
Ext Dose	Upper Bound	UB β+γ	No Potential for Exposure																			
NPE+	NPE	total	No Potential for Exposure																			

* The total organ doses do not sum up to its components due to rounding.

† UB means upper bound dose for the given radiation type.

+ NPE means No potential for Exposure

Table 5. Estimated Radiation Doses (rem) for Land-Based Personnel at the Pacific Proving Ground

EPG Name		Radiation Type†	Adrenals	Bone Surface	Brain	Breast	Stomach wall	Small Intestine wall	Upper Large Intestine Wall	Lower Large Intestine Wall	Kidneys	Liver	Extra-Thoracic Region	Lung	Muscle	Pancreas	Red Marrow	Spleen	Testes	Thymus	Thyroid	Urinary Bladder Wall
CROSSROADS Land		UB α	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext Dose	UB β+γ	UB β+γ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.03	0.09	total	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
BIKINI Resurvey		UB α	0.09	49	0.09	0.09	0.09	0.09	0.09	0.09	0.3	11	0.5	1	0.09	0.09	3	0.09	0.7	0.09	0.09	0.09
Ext Dose	Upper Bound	UB β+γ	0.02	1	0.007	0.01	0.02	0.03	0.1	0.3	0.01	0.3	0.2	3	0.008	0.01	0.08	0.01	0.02	0.02	0.008	0.008
0.8	3	total	3	52	3	3	3	3	3	3	3	14	3	6	3	3	5	3	4	3	3	3
SANDSTONE Land		UB α	<0.001	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.1	0.005	0.01	<0.001	0.002	0.03	0.003	0.006	<0.001	0.002	<0.001
Ext Dose	Upper Bound	UB β+γ	0.007	0.07	0.003	0.006	0.02	0.03	0.2	0.3	0.005	0.02	0.4	0.8	0.005	0.006	0.03	0.005	0.003	0.007	0.6	0.01
0.2	0.6	total	0.6	1	0.6	0.6	0.6	0.6	0.7	0.8	0.6	0.7	0.9	2	0.6	0.6	0.6	0.6	0.6	0.6	1	0.6
GREENHOUSE Land		UB α	0.005	3	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.6	0.03	0.06	0.005	0.005	0.2	0.005	0.04	0.005	0.005	0.005
Ext Dose	Upper Bound	UB β+γ	0.2	2	0.08	0.2	0.9	2	5	8	0.2	0.3	12	15	0.2	0.2	0.5	0.2	0.06	0.2	16	0.4
7	21	total	21	25	21	21	22	23	26	29	21	22	33	36	21	21	22	21	21	21	36	22
IVY Land		UB α	0.002	2	0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.3	0.02	0.03	0.002	0.002	0.06	0.002	0.02	0.002	0.002	0.002
Ext Dose	Upper Bound	UB β+γ	0.02	0.7	0.007	0.02	0.04	0.08	0.4	0.7	0.02	0.2	1	3	0.02	0.02	0.08	0.02	0.009	0.02	0.8	0.02
0.2	0.4	total	0.4	3	0.4	0.4	0.4	0.5	0.7	1	0.4	0.7	2	3	0.4	0.4	0.5	0.4	0.4	0.4	2	0.4
CASTLE Land		UB α	0.02	7	0.02	0.02	0.02	0.02	0.02	0.02	0.03	2	0.07	0.2	0.02	0.02	0.4	0.02	0.1	0.02	0.02	0.02
Ext Dose	Upper Bound	UB β+γ	0.1	5	0.05	0.08	0.5	0.9	4	7	0.2	0.9	11	15	0.08	0.09	0.4	0.08	0.08	0.1	8	0.2
2	5	total	5	16	5	5	6	6	8	12	5	7	16	20	5	5	6	5	5	5	13	5
REDWING Land		UB α	0.02	9	0.02	0.02	0.02	0.02	0.02	0.02	0.04	2	0.09	0.2	0.02	0.02	0.5	0.02	0.2	0.02	0.02	0.02
Ext Dose	Upper Bound	UB β+γ	0.2	5	0.2	0.2	2	3	9	16	0.4	0.9	25	30	0.2	0.2	0.7	0.2	0.2	0.3	23	0.6
6	18	total	19	31	18	18	20	21	27	34	19	21	43	48	18	18	19	18	19	19	41	19

Table 5. Estimated Radiation Doses (rem) for Land-Based Personnel at the Pacific Proving Ground (cont.)

EPG Name		Radiation Type†	Adrenals	Bone Surface	Brain	Breast	Stomach wall	Small Intestine wall	Upper Large Intestine Wall	Lower Large Intestine Wall	Kidneys	Liver	Extra-Thoracic Region	Lung	Muscle	Pancreas	Red Marrow	Spleen	Testes	Thymus	Thyroid	Urinary Bladder Wall
HARDTACK I Land		UB α	0.02	12	0.02	0.02	0.02	0.02	0.02	0.02	0.06	3	0.2	0.3	0.02	0.02	0.6	0.02	0.2	0.02	0.02	0.02
Ext Dose	Upper Bound	UB β+γ	0.2	3	0.07	0.2	0.4	0.8	4	8	0.6	0.6	12	11	0.2	0.2	0.5	0.5	0.08	0.2	11	0.6
3	8	total	8	22	8	8	8	9	12	16	9	11	20	19	8	8	9	9	8	8	19	9
DOMINIC I Land		UB α	No Potential for Exposure																			
Ext Dose	Upper Bound	UB β+γ	No Potential for Exposure																			
NPE+	NPE+	total	No Potential for Exposure																			

* The total organ doses do not sum up to its components due to rounding.

† UB means upper bound dose for the given radiation type.

+ NPE means no potential for exposure from either external or internal radiation. If film badge dosimetry exists, assign film badge dose as the upper-bound external gamma dose.

Table 6. Estimated Radiation Doses (rem) for Post-Operations Personnel at the Pacific Proving Ground*

EPG Name		Radiation Type†	Adrenals	Bone Surface	Brain	Breast	Stomach wall	Small Intestine wall	Upper Large Intestine Wall	Lower Large Intestine Wall	Kidneys	Liver	Extra-Thoracic Region	Lung	Muscle	Pancreas	Red Marrow	Spleen	Testes	Thymus	Thyroid	Urinary Bladder Wall
POST-SANDSTONE		UB α	<0.001	0.08	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	0.002	<0.001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	0.002	0.02	<0.001	0.002	0.002	0.002	0.009	0.03	<0.001	0.003	0.03	0.2	<0.001	<0.001	0.005	<0.001	<0.001	0.002	0.009	<0.001
0.05	0.2	total	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
POST-GREENHOUSE		UB α	0.004	3	0.004	0.004	0.004	0.004	0.004	0.004	0.009	0.5	0.03	0.05	0.004	0.004	0.1	0.004	0.03	0.004	0.004	0.004
Ext Dose	Upper Bound	UB β+γ	0.06	0.6	0.02	0.05	0.07	0.2	0.5	2	0.04	0.1	2	7	0.04	0.05	0.3	0.04	0.02	0.06	2	0.04
3	8	total	8	10	8	8	8	8	8	9	8	8	9	14	8	8	8	8	8	8	9	8
POST-IVY		UB α	<0.001	0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	0.002	0.003	<0.001	<0.001	0.006	<0.001	0.002	<0.001	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	<0.001	0.07	<0.001	<0.001	<0.001	<0.001	0.004	0.009	<0.001	0.02	0.02	0.05	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.01	<0.001
0.03	0.09	total	0.09	0.3	0.09	0.09	0.09	0.09	0.09	0.1	0.09	0.2	0.1	0.2	0.09	0.09	0.1	0.09	0.09	0.09	0.1	0.09
POST-CASTLE		UB α	0.006	3	0.006	0.006	0.006	0.006	0.006	0.006	0.02	0.7	0.03	0.07	0.006	0.04	0.006	0.2	0.006	0.006	0.05	0.006
Ext Dose	Upper Bound	UB β+γ	0.008	2	0.005	0.008	0.008	0.02	0.04	0.1	0.008	0.4	0.2	0.8	0.006	0.03	0.007	0.08	0.005	0.007	0.03	0.009
0.3	0.8	total	0.8	6	0.8	0.8	0.8	0.8	0.8	0.9	0.8	2	0.9	2	0.8	0.8	0.8	1	0.8	0.8	0.8	0.8
POST-REDWING		UB α	0.02	8	0.02	0.02	0.02	0.02	0.02	0.02	0.04	2	0.08	0.2	0.02	0.02	0.4	0.02	0.2	0.02	0.02	0.02
Ext Dose	Upper Bound	UB β+γ	0.05	3	0.02	0.05	0.06	0.09	0.4	1	0.04	0.5	2	7	0.03	0.04	0.3	0.04	0.04	0.06	0.8	0.03
2	6	total	6	16	6	6	6	6	7	7	6	8	7	12	6	6	7	6	6	6	7	6
POST-HARDTACK I		UB α	0.006	4	0.006	0.006	0.006	0.006	0.006	0.006	0.02	0.7	0.04	0.08	0.006	0.006	0.2	0.006	0.05	0.006	0.006	0.006
Ext Dose	Upper Bound	UB β+γ	0.009	0.5	0.004	0.007	0.02	0.02	0.2	0.4	0.06	0.1	0.4	1	0.005	0.007	0.05	0.05	0.007	0.008	0.02	0.02
0.4	1	total	1	5	1	1	1	1	2	2	2	2	2	3	1	1	2	2	2	1	1	1

* The total organ doses do not sum up to its components due to rounding.

† UB means upper bound dose for the given radiation type.

Table 7. Estimated Radiation Doses (rem) for Personnel at the Nevada Test Site*

EPG Name		Radiation Type†	Adrenals	Bone Surface	Brain	Breast	Stomach wall	Small Intestine wall	Upper Large Intestine Wall	Lower Large Intestine Wall	Kidneys	Liver	Extra-Thoracic Region	Lung	Muscle	Pancreas	Red Marrow	Spleen	Testes	Thymus	Thyroid	Urinary Bladder Wall
NTS OBS/Man		UB α	0.008	5	0.008	0.008	0.008	0.008	0.008	0.008	0.02	1	0.05	0.1	0.008	0.008	0.3	0.008	0.06	0.008	0.008	0.008
Ext Dose	Upper Bound	UB β+γ	0.02	0.2	0.006	0.01	0.05	0.07	0.2	0.4	0.009	0.03	0.7	2	0.009	0.02	0.05	0.01	0.005	0.02	0.8	0.02
4	10	total	10	14	10	10	10	10	10	10	10	11	11	11	10	10	10	10	10	10	11	10
NTS Support Troops		<0.001	0.005	<0.001	<0.001	<0.001	0.001	0.004	0.006	<0.001	0.002	0.009	0.009	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	<0.001
Ext Dose	Upper Bound	UB β+γ	<0.001	0.05	<0.001	<0.001	0.006	0.009	0.03	0.05	<0.001	0.02	0.09	0.09	<0.001	<0.001	0.004	<0.001	0.001	0.001	0.2	0.003
0.04	0.1	total	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.2
2MCPAEB		UB α	0.003	2	0.003	0.003	0.003	0.003	0.003	0.003	0.007	0.4	0.02	0.04	0.003	0.003	0.09	0.003	0.03	0.003	0.003	0.003
Ext Dose	Upper Bound	UB β+γ	0.03	0.3	0.02	0.02	0.2	0.2	0.6	2	0.02	0.04	2	3	0.02	0.02	0.08	0.02	0.009	0.03	2	0.05
6	17	total	17	19	17	17	17	17	17	18	17	17	19	20	17	17	17	17	17	17	19	17
TF WARRIOR		UB α	0.02	10	0.02	0.02	0.02	0.02	0.02	0.02	0.05	2	0.2	0.4	0.02	0.02	0.5	0.02	0.2	0.02	0.02	0.02
Ext Dose	Upper Bound	UB β+γ	0.09	2	0.06	0.07	0.7	1	3	4	0.08	0.4	9	8	0.08	0.09	0.4	0.08	0.06	0.1	9	0.3
2	5	total	5	16	5	5	6	6	8	9	5	7	13	12	5	5	6	5	5	5	13	5

* The total organ doses do not sum up to its components due to rounding.

† UB means upper bound dose for the given radiation type.

To evaluate the impact of using either absorption type, alpha particle doses for the isotopes of the elements mentioned above were calculated using an adjustment factor determined from the ratios of the ICRP dose coefficients for type S to the dose coefficients for type M for the ET region and lung for each alpha particle emitter (i.e. U-235, U-238, Np-237, Pu-238, Pu-239, Pu-240, Am-241, and Cm-242). Those ratios were found to range from 2.1 to 6.0 for the ET region and from 1.4 to 3.0 for the lung. To maximize the estimates of alpha and therefore total doses, ratios of 6.0 and 3.0 were used for the ET region and the lung, respectively. The results of those calculations, and a comparison of the alpha doses and total doses using absorption types M and S are listed in Table 8.

Table 8. Comparison of Alpha Particle and Total Doses for Type M and Type S

EPG			**ET Region (Type M)**	**ET Region (Type S)**	**% diff (M-S)/S**	**Lung (Type M)**	**Lung (Type S)**	**% diff (M-S)/S**
Screening Dose (rem)			**35 (Esophagus)**			**54 (Lung)**		
XRDS Target Ship		alpha UB	0.465	2.79	**-83%**	1.03	3.09	**-67%**
Ext EPG Dose / UB		b+g UB	8.95	8.95		18.3	18.3	
2.88	8.65	total	18.1	20.4	**-11%**	28	30	**-7%**
XRDS Sup Ship		alpha UB	0.0128	0.0768	**-83%**	0.0283	0.0849	**-67%**
Ext EPG Dose / UB		b+g UB	0.108	0.108		0.321	0.321	
2.72	8.15	total	8.27	8.33	**-1%**	8.5	8.56	**-1%**
USS BRUSH		alpha UB	0.462	2.77	**-83%**	1.01	3.04	**-67%**
Ext EPG Dose / UB		b+g UB	0.474	0.474		3.66	3.66	
0.08	0.24	total	1.17	3.48	**-66%**	4.91	6.93	**-29%**
SANDSTONE Ship		alpha UB	3.81E-05	0.000229	**-83%**	8.45E-05	0.000254	**-67%**
Ext EPG Dose / UB		b+g UB	0.0182	0.0182		0.0262	0.0262	
0.0862	0.258	total	0.277	0.277	**0%**	0.285	0.285	**0%**
GREENHOUSE Ship		alpha UB	0.000932	0.00559	**-83%**	0.00207	0.0062	**-67%**
Ext EPG Dose / UB		b+g UB	1.96	1.96		2.13	2.13	
2.04	6.12	total	8.08	8.08	**0%**	8.25	8.25	**0%**
IVY Ship		alpha UB	0.000217	0.0013	**-83%**	0.000478	0.00143	**-67%**
Ext EPG Dose / UB		b+g UB	0.0496	0.0496		0.0721	0.0721	
0.0624	0.187	total	0.237	0.238	**0%**	0.26	0.261	**0%**
CASTLE (High) Ship		alpha UB	0.0473	0.284	**-83%**	0.104	0.313	**-67%**
Ext EPG Dose / UB		b+g UB	20.6	20.6		23.9	23.9	
7.43	22.3	total	43.0	43.2	**0%**	46.3	46.5	**0%**
CASTLE (Low) Ship		alpha UB	0.0647	0.388	**-83%**	0.142	0.427	**-67%**
Ext EPG Dose / UB		b+g UB	7.91	7.91		11.2	11.2	
3.81	11.4	total	19.4	19.7	**-2%**	22.7	23	**-1%**

Table 8. Comparison of Alpha Particle and Total Doses for Type M and Type S (cont.)

EPG			ET Region (Type M)	ET Region (Type S)	% diff (M-S)/S	Lung (Type M)	Lung (Type S)	% diff (M-S)/S
WIGWAM Ship		alpha UB	0.00113	0.00679	**-83%**	0.00251	0.00753	**-67%**
Ext EPG Dose / UB		b+g UB	0.737	0.737		0.686	0.686	
0.230	0.557	total	1.3	1.3	**0%**	1.25	1.25	**0%**
REDWING Ship		alpha UB	0.000829	0.00498	**-83%**	0.00183	0.0055	**-67%**
Ext EPG Dose / UB		b+g UB	1.16	1.16		1.54	1.54	
2.01	6.04	total	7.2	7.21	**0%**	7.58	7.59	**0%**
HARDTACK I Ship		alpha UB	0.0151	0.0907	**-83%**	0.0351	0.105	**-67%**
Ext EPG Dose / UB		b+g UB	2.52	2.52		2.2	2.2	
1.94	5.81	total	8.34	8.42	**-1%**	8.04	8.11	**-1%**
CROSSROADS Land		alpha UB	0.00	0.00	**0%**	0.00	0.00	**0%**
Ext EPG Dose / UB		b+g UB	0.00	0.00		0.00	0.00	
0.03	0.09	total	0.09	0.09	**0%**	0.09	0.09	**0%**
BIKINI Resurvey		alpha UB	0.485	2.91	**-83%**	1.08	3.23	**-67%**
Ext EPG Dose / UB		b+g UB	0.175	0.175		2.45	2.45	
0.779	2.34	total	3	5.42	**-45%**	5.86	8.01	**-27%**
SANDSTONE Land		alpha UB	0.00437	0.0262	**-83%**	0.00968	0.029	**-67%**
Ext EPG Dose / UB		b+g UB	0.354	0.354		0.737	0.737	
0.17	0.511	total	0.869	0.891	**-2%**	1.26	1.28	**-2%**
GREENHOUSE Land		alpha UB	0.0268	0.161	**-83%**	0.0593	0.178	**-67%**
Ext EPG Dose / UB		b+g UB	11.9	11.9		14.9	14.9	
6.91	20.7	total	32.7	32.8	**0%**	35.7	36	**-1%**
IVY Land		alpha UB	0.0144	0.0862	**-83%**	0.027	0.0809	**-67%**
Ext EPG Dose / UB		b+g UB	0.974	0.974		2.22	2.22	
0.109	0.326	total	1.31	1.39	**-6%**	2.58	2.63	**-2%**
CASTLE Land		alpha UB	0.0672	0.403	**-83%**	0.144	0.431	**-67%**
Ext EPG Dose / UB		b+g UB	10.4	10.4		14.9	14.9	
1.55	4.66	total	15.2	15.5	**-2%**	19.7	20	**-2%**
REDWING Land		alpha UB	0.0879	0.528	**-83%**	0.193	0.578	**-67%**
Ext EPG Dose / UB		b+g UB	24.5	24.5		29.4	29.4	
5.93	17.8	total	42.4	42.8	**-1%**	47.4	47.8	**-1%**
HARDTACK I Land		alpha UB	0.116	0.697	**-83%**	0.268	0.805	**-67%**
Ext EPG Dose / UB		b+g UB	11.4	11.4		10.6	10.6	
2.52	7.56	total	19.1	19.7	**-3%**	18.4	18.9	**-3%**
POST-SANDSTONE		alpha UB	0.000793	0.00476	**-83%**	0.00175	0.00525	**-67%**
Ext EPG Dose / UB		b+g UB	0.0236	0.0236		0.14	0.14	
0.05	0.14	total	0.16	0.164	**-2%**	0.277	0.281	**-1%**

Table 8. Comparison of Alpha Particle and Total Doses for Type M and Type S (cont.)

EPG			ET Region (Type M)	ET Region (Type S)	% diff (M-S)/S	Lung (Type M)	Lung (Type S)	% diff (M-S)/S
POST-GREENHOUSE		alpha UB	0.0203	0.122	**-83%**	0.0448	0.135	**-67%**
Ext EPG Dose / UB		b+g UB	1.49	1.49		6.28	6.28	
2.44	7.32	total	8.83	8.93	**-1%**	13.6	13.7	**-1%**
POST_IVY		alpha UB	0.00106	0.00637	**-83%**	0.00234	0.00702	**-67%**
Ext EPG Dose / UB		b+g UB	0.0104	0.0104		0.0476	0.0476	
0.03	0.08	total	0.0949	0.11	**-14%**	0.133	0.138	**-4%**
POST-CASTLE		alpha UB	0.0283	0.17	**-83%**	0.0623	0.187	**-67%**
Ext EPG Dose / UB		b+g UB	0.104	0.104		0.796	0.796	
0.25	0.74	total	0.867	1.01	**-14%**	1.59	1.72	**-8%**
POST-REDWING		alpha UB	0.0736	0.441	**-83%**	0.162	0.486	**-67%**
Ext EPG Dose / UB		b+g UB	1.16	1.16		6.07	6.07	
1.91	5.73	total	6.96	7.4	**-6%**	12	12.3	**-2%**
POST-HARDTACK I		alpha UB	0.0333	0.2	**-83%**	0.0772	0.232	**-67%**
Ext EPG Dose / UB		b+g UB	0.302	0.302		0.995	0.995	
0.36	1.07	total	1.41	1.57	**-10%**	2.14	2.3	**-7%**
NTS OBS/Man		alpha UB	0.0418	0.251	**-83%**	0.0926	0.278	**-67%**
Ext EPG Dose / UB		b+g UB	0.696	0.696		1.17	1.17	
3.13	9.40	total	10.1	10.3	**-2%**	10.7	10.8	**-1%**
NTS Support Troops		alpha UB	0.00823	0.0494	**-83%**	0.00847	0.0254	**-67%**
Ext EPG Dose / UB		b+g UB	0.0822	0.0822		0.0847	0.0847	
0.032	0.097	total	0.188	0.229	**-18%**	0.19	0.207	**-8%**
2MCPAEB		alpha UB	0.0166	0.0993	**-83%**	0.0367	0.11	**-67%**
Ext EPG Dose / UB		b+g UB	1.9	1.9		2.7	2.7	
5.48	16.32	total	18.2	18.3	**-1%**	19.1	19.1	**0%**
TF WARRIOR		alpha UB	0.122	0.731	**-83%**	0.331	0.993	**-67%**
Ext EPG Dose / UB		b+g UB	8.05	8.05		7.12	7.12	
1.51	4.53	total	12.7	13.3	**-5%**	12	12.6	**-5%**

The doses for ET region and lung calculated using the dose coefficients for type M are lower than those using type S. The total doses are generally lower by no more than 20 percent except for the USS Brush, and Bikini Resurvey EPGs, which are both considered non-participants. The total doses for ET region exceed the screening dose calculated for the CASTLE (High) Ship EPG and the REDWING Land EPG. However, both of those total doses calculated for Type M also exceeded the screening dose. Therefore, using the doses based on absorption type S for alpha emitting radionuclides results in no changes to the overall utility of the doses for expedited processing. These alternate alpha doses should be considered during the implementation of the revised approach to expedited processing.

5.3 Expedited Processing Groups and Organ Combinations not Recommended for Expedited Processing

The overall EPG upper-bound organ dose that results from combining external and internal upper-bound EPG doses for 20 organs and 29 EPGs—those EPGs for which there was potential for exposure to radiation—were compared with the organ/cancer screening doses listed in Section 2, Table 3. This evaluation process is discussed in detail in Section 3. If an EPG upper-bound organ dose is higher than its respective screening dose, it is recommended that the EPG/organ combination be excluded from expedited processing. For those EPG/organ combinations where the overall EPG upper-bound dose falls between the doses listed in Table 3 that roughly correspond to the limiting dose (40-percent PC) and screening dose (50-percent PC), the NIOSH-IREP software is employed to calculate the PC using the EPG upper-bound doses for each type of radiation. If the PC is higher than or equal to 40 percent, the EPG/organ combination is added to the list of cases not suitable for expedited processing. Only the EPG/organ combinations for which the NIOSH-IREP estimated PC is lower than 40 percent are deemed eligible for expedited processing.

The EPG upper-bound doses to 20 organs for the aforementioned 29 EPGs constitute 580 total upper-bound organ doses calculated. These doses were compared with the screening doses for 27 NIOSH-IREP cancer models. Because 10 of the 20 organ doses were applicable to multiple cancer models, there were 37 dose/cancer model comparisons made for each EPG, resulting in a total of over 1,000 comparisons of EPG/organ doses to cancer model screening doses. The relationship of FIIDOS organs to relevant cancer models with the corresponding screening doses are shown in Table 9.

Of these comparisons, only 68 EPG/organ combinations did not satisfy the criterion that the overall EPG upper-bound dose is well below the screening dose. About half of those situations occur for three relatively high-dose EPGs—Operation CASTLE high-dose ship-based personnel, Operation REDWING land-based personnel, and Operation GREENHOUSE land-based personnel—for about 10 cancer models each. Approximately two-thirds of the 68 EPG/organ sets are associated with cancers of the liver/gallbladder/bile duct (25 occurrences) and thyroid (20 occurrences). This large number of occurrences is due, in part, to cancers of the liver and thyroid having the lowest screening doses for the age at exposure and age at diagnosis of most NTPR claims. The remaining organs that did not satisfy the well-below criterion relate to the bone surface (six occurrences), red marrow (five occurrences), stomach (three occurrences), lower large intestine (three occurrences), extra-thoracic region (three occurrences), and lung (three occurrences). The chart in Table 10 shows all occurrences as EPG/organ combinations with the relevant cancer models. For the NTS Observers and Maneuver Troops EPG, the total upper bound doses relevant to the gall bladder, bile duct, and acute lymphocytic leukemia do not satisfy the well-below criterion when the initial doses (neutron and gamma) accrued by the Observers at Shot TESLA, Operation TEAPOT are added to the EPG upper-bound external plus internal doses from residual radiation.

Table 9. Dose Reconstruction Organs and Corresponding NIOSH-IREP Cancer Models Used in NTPR

NTPR Standard Organ IREP Cancer	SD* (rem)	NTPR Standard Organ IREP Cancer	SD* (rem)	NTPR Standard Organ IREP Cancer	SD* (rem)	NTPR Standard Organ IREP Cancer	SD* (rem)	NTPR Standard Organ IREP Cancer	SD* (rem)
Adrenals		**Bone Surface**		**Brain**		**Breast**		**Stomach Wall**	
Other Endocrine Glands	45	Bone	48	Other Endocrine Glands	45	Breast	53	Stomach	27
				Nervous system	95				
				Eye	49				
				Other Respiratory	100				
Small Intestine Wall		**Upper Large Intestine Wall**		**Lower Large Intestine Wall**		**Kidneys**		**Liver**	
All digestive	66	Colon	39	Colon	39	Urinary Organs	46	Liver	11
				Rectum	110			Gallbladder	17
Extra-Thoracic Region		**Lung**		**Muscle**		**Pancreas**		**Red Marrow**	
Esophagus	35	Lung	45	Connective Tissue	50	Pancreas	89	Acute Lymphocytic Leukemia	24
Oral Cavity and Pharynx	98	Other Respiratory	100	Other and Ill-Defined Sites	50			Acute Myeloid Leukemia	29
Other Respiratory	100			All Digestive	66			Leukemia	41
				Other Respiratory	100			Bone	48
Spleen		**Testes**		**Thymus**		**Thyroid**		**Urinary Bladder Wall**	
Lymphoma	61	All Male Genitalia	60	Lymphoma	61	Thyroid	7.5	Urinary Organs	46
				Other Respiratory	100	Other Endocrine Glands	45	Bladder	49

* SD is the screening dose for age of exposure of 18 years and time elapsed of 32 years and for a probability of causation of 50 percent at the upper 99 percentile credibility limit (Kocher and Apostoaei, 2007).

Table 10. EPG and Organ Combinations not Recommended for Expedited Processing (Highlighted Cells)

NTPR Standard Organ	Adrenals	Bone	Brain				Breast	St Wall	SI Wall	ULI Wall	LLI Wall		Kidneys	Liver		ET Region			Lung		Muscle				Pancreas	Red Mar				Spleen	Testes	Thymus		Thyroid		Bladder	
NIOSH-IREP Cancer Model	Adrenals	Bone	Endocrine	Nervous sys	Eye	Other resp.	Breast	Stomach	All Digest	Colon	Colon	Rectum	Kidneys	Liver	Gall Bladder, Bile Duct	Esophagus	Oral Cavity	Other resp.	Lung	Other Resp.	Conn Tissue	Ill-defined	All digest	Other resp.	Pancreas	ALL*	AML†	Leukemia	Bone	Spleen	Testes	Lymphoma	Other resp.	Thyroid	Other Endo.	Urinary orgs	Bladder
PPG, Ship-Based Personnel‡																																					
XRD Support Ships														■																				■			
XRD Target Ships		■												■	■																			■	■		
USS BRUSH (1947)		■												■	■																						
SS																																					
IVY																																					
GH																																		■			
CSTL (High)		■						■			■			■	■	■			■							■	■							■	■		
CSTL (Low)														■	■																			■			
REDWING																																		■			
WIGWAM																																					
HT I																																		■			
ARGUS																																					
HT I Ships Unexposed																																					
DOM I																																					
PPG, Land-Based Personnel‡																																					
XRD																																					
Bikini Resurvey (1947)		■												■	■																						
SS																																					
GH								■			■			■	■	■			■							■								■	■		
IVY																																					
CSTL														■																				■			
REDWING		■						■			■			■	■	■			■							■								■	■		
HT-I		■												■	■																			■			

Table 10. EPG and Organ Combinations not recommended for Expedited Processing (Highlighted Cells) (cont.)

NTPR Standard Organ	Adrenals	Bone	Brain				Breast	St Wall	SI Wall	ULI Wall	LLI Wall		Kidneys	Liver		ET Region			Lung		Muscle				Pancreas	Red Mar				Spleen	Testes	Thymus		Thyroid		Bladder	
NIOSH-IREP Cancer Model	Adrenals	Bone	Endocrine	Nervous sys	Eye	Other resp.	Breast	Stomach	All Digest	Colon	Colon	Rectum	Kidneys	Liver	Gall Bladder, Bile Duct	Esophagus	Oral Cavity	Other resp.	Lung	Other Resp.	Conn Tissue	Ill-defined	All digest	Other resp.	Pancreas	ALL*	AML†	Leukemia	Bone	Spleen	Testes	Lymphoma	Other resp.	Thyroid	Other Endo.	Urinary orgs	Bladder
PPG, Inter-Operation Personnel‡																																					
Post-SS																																					
Post-GH																																					
Post-IVY																																					
Post-CSTL																																					
Post-RW																																					
Post-HT-I																																					
Nevada Test Site Personnel‡																																					
Observers and Maneuver																																					
Camp Desert Rock Support																																					
2MCPAEB																																					
Task Force WARRIOR (PB)																																					

* Acute Lymphocytic Leukemia.

† Acute Myeloid Leukemia.

‡ PPG=Pacific Proving Ground, XRD=CROSSROADS, SS=SANDSTONE, GH=GREENHOUSE, CSTL=CASTLE, RW=REDWING, HTI=HARDTACK I, DOM I=DOMINIC I, PB=PLUMBBOB, 2MCPAEB=2nd Marine Corps Atomic Exercise Brigade.

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6.

Summary and Conclusions

The overall objectives of this study are to evaluate and update the technical approach for expediting NTPR cases and to use this approach to estimate doses for the broadest number of participants. Additionally, the effort required an evaluation of the association between those doses and specific cancers to assess if they are well below the respective screening doses that produce a PC of 50 percent at the upper 99th percentile. The study objectives have been met through the completion of a pilot phase and a subsequent developmental phase during which the proposed technical approach was researched, established, and applied successfully to estimate doses for expedited processing that are supported by sound technical methods.

The recommended approach is developed by first identifying large groups of NTPR participants who were exposed under similar conditions (the EPGs), and then for each EPG estimating doses on the basis of the "highest-dose cohort" concept that is further refined by substituting dose components and maximizing input parameters. This approach ensures that the doses assigned to an EPG bound any plausible doses actually accrued by any member.

6.1 Pilot Phase

The pilot phase of this study was conducted to address several of the preliminary objectives. Early in this phase it was concluded that the use of historical RDA doses for expedited processing was not always adequate. The pilot phase was subsequently used to develop and test an approach for estimating doses for expedited processing through scenario-based dose assessments for large groups of NTPR participants and the "highest-dose cohort" concept. The pilot phase also resulted in proposing a set of standardized names and associations between a diseased organ, the corresponding organ for which doses are calculated, and the IREP cancer risk model used to estimate a probability of causation.

A thorough review of three sets of data elements—discussed below—used by DTRA, VA, and contractors to develop doses for claimed diseases resulted in a clearer understanding of the associations among these claimed diseases, the dose conversion factors appropriate to diseased organs, and the cancer models used to evaluate the probability of causation. This effort addressed two key objectives of the study involving the determination of the appropriateness of previously reported veteran doses for use in expedited processing, and the development of standardized and consistent organ dose processing tables. As a result, a proposed inter-relationship of terms was prepared for the diseases specified in claims, called NTPR NuTRIS Organ Codes; the NTPR Standard Organs used to calculate doses from exposures to internally deposited radioactive materials; and the cancer types, called NIOSH-IREP cancer models, used

to estimate the degree of association of a cancer with a given radiation dose to an organ or tissue. The proposed inter-relationships are included in Table A-1 (Appendix A). This table is proposed as the basis for implementation of future expedited processing as well as for other RDAs. The pilot phase successfully demonstrated the approach using sample groups of NTPR participants and resulted in the conclusion that the approach should be applied to the broader population of all NTPR participants.

6.2 Developmental Phase

During the developmental phase of the study, a total of 32 EPGs were identified that collectively address the majority of PPG and NTS participants. Nine sample EPGs, evaluated and reported in the Interim Report of the Pilot Phase of this study, were expanded by aggregating similar cohort groups and by applying the experimental approach to other test operations. As important as identifying the participants that are covered by these EPGs is the explicit identification of those participants whose possible exposure scenarios are too complex or not sufficiently characterized to include in a general expedited process. The participants who are not recommended for expedited processing are identified and their cases recommended for further review and eventually a detailed assessment.

The rationale for the makeup of the proposed EPGs are discussed in Section 4 of this report with details of corresponding dose assessments included in the accompanying EPG Compendium (DTRA, 2011). The EPG RDA reports that make up the compendium describe the personnel who comprise each EPG and the details of their scenarios of exposure, maximizing assumptions, and input parameter values employed in the dose estimation. This information was used to develop detailed calculation worksheets that fully document the dose estimates and support independent reviews. In addition to their use in developing the proposed EPG doses and upper bounds, the calculation tools would facilitate efficient evaluations of future individual NTPR RDA cases. Additionally, to help ensure appropriate implementation of expedited processing of NTPR RDA cases, the discussions for the 32 EPGs provide the detailed listings of units and cohorts that encompass the membership of each EPG (DTRA, 2011).

Furthermore, the units, groups and activities that should be excluded from expedited processing are identified in DTRA (2011) and in Appendix B of this report. Some potential cohorts proposed for certain EPGs were found to be associated with special activities and exposures and were assigned to excluded categories that could not be processed using expedited procedures. The members of these cohorts were identified as having been involved in unique activities characterized by large variations in radiation sources, exposure rates, exposure durations, and timing of exposures. In addition, activities that could produce significantly higher doses for a participant than for most EPG members were identified as general exclusions requiring a case-specific review and eventually a detailed dose assessment.

Similarity of the exposure scenarios for many of the NTS participants allowed their consolidation into more broadly defined exposure groups. Consequently, the 32 EPGs consist of only four EPGs for the NTS, and 28 EPGs for the PPG. The PPG EPGs are further subdivided into 22 EPGs representing participation during actual test operations and six EPGs covering individuals with activities that occurred in time periods after or between test operations. The

PPG EPGs for test operations are subdivided into land-based, ship-based, and other groups consisting of cohorts with unique exposure circumstances.

6.3 Results of the Study

Scenario-based external and internal doses have been calculated for each EPG that are consistent across radiation types and affected organs and are proposed for assignment for expedited processing of NTPR cases. The EPG doses and their upper bounds consist of high-sided estimates calculated using highly conservative scenarios of exposure and the highest plausible input parameter values. These doses are from exposure to external gamma radiation, internal alpha radiation, and internal beta-plus-gamma radiation for the 20 relevant NTPR Standard Organs; ovaries, uterus, and skin are not included. The upper-bound doses were calculated to meet the criteria recommended by the VBDR that they should be based on worst case parameters and assumptions and that they should be higher than any realistically-calculated veteran's upper-bound doses. Across all EPGs, the estimated upper-bound external doses range from less than 0.1 to 23 rem. Similar but wider ranges are observed for internal organ doses (DTRA, 2011).

The total organ doses that result from combining the external and internal upper-bound doses for each of the 20 organs in each of the 29 EPGs, for which there was the potential for radiation exposure, were compared with the organ/cancer screening doses discussed in Section 2. The comparison was performed to assess whether the total organ doses were well below the screening doses for each assessed cancer. This evaluation addressed the study objective related to estimating the association between radiation exposure and cancer disease. Of over 1,000 comparisons of total EPG/organ upper-bound dose with the corresponding screening dose, only 68 did not satisfy the criterion of being well below the screening doses. The 68 EPG/organ combinations are shown in Section 5 of this report and in the EPG Compendium (DTRA, 2011).

Roughly half of those situations occurred for three EPGs—Operation CASTLE high-dose, ship-based personnel, Operation REDWING land-based personnel, and Operation GREENHOUSE land-based personnel—involving about 10 cancer models each. Approximately two-thirds of these 68 total organ upper-bound doses were associated with cancers of the liver and thyroid, which have the lowest screening doses for age at exposure and age at diagnosis of cancer for most NTPR claims. The remaining total organ upper-bound doses that did not satisfy the well-below criterion involve the bone surface, red marrow, stomach, lower large intestine, extra-thoracic region, and lung. This implies that the vast majority of NTPR cases should be suitable for expedited processing with this methodology.

The scenario-based approach for expedited processing has proven to be a valuable technique for identifying EPGs and producing upper-bound doses that are well below the screening doses for most organs. However, this approach is not useful for identifying cases with upper-bound doses that are comparable to or above the screening dose because any one individual and any one cohort is likely to have an upper-bound dose below the total EPG upper-bound dose. For the 68 EPG/organ combinations that do not satisfying the "well below" criterion, the estimated EPG doses are not suitable and relevant cases are not recommended for expedited processing. Rather,

a review of the veteran-specific information and eventually a detailed assessment should be performed.

7.

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Appendix A.

Cross Reference of NTPR NuTRIS Organ Codes, NTPR Standard Organs and NIOSH-IREP Cancer Risk Models

This appendix provides a listing (Table A-1) of NTPR NuTRIS Organ Codes and their associated descriptions cross referenced to the NTPR Standard Organs used in FIIDOS internal dose calculations and the cancer risk models of NIOSH-IREP. Entries in the Surrogate Type column describe whether the assignment in the NTPR Standard Organ column is an actual NTPR Standard Organ used in FIIDOS calculations (FIIDOS), or an NTPR Standard Organ selected as a surrogate for the NTPR NuTRIS Organ Code (Surrogate).

The table contains entries in the "Current NTPR NuTris Code" and "Proposed NuTris Code" columns. The proposed codes are suggested for use in future dose reconstruction cases to provide improved consistency, eliminate duplicate organ entries, remove entries that are not organs or tissues, and provide the foundations for lookup of NTRP NuTris Codes and NTPR Standard Organs / Surrogates.

In addition, 16 new combinations, shown in *italics*, are included based on an assessment of cancer models and associated organs found in NIOSH-IREP documentation. These suggestions have been developed in the interest of possible future implementation to improve harmonization of references within the VA and DTRA processes.

Comments are included for entries that require clarification or further study before the NTPR Standard Organ and NIOSH-IREP cancer risk model(s) can be selected.

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
ADR-GL	ADR-GL	Adrenal Gland	Adrenals	FIIDOS	Other Endocrine Glands (194)	
ANKLE	BON-ANKLE	Bone (Ankle)	Bone Surface	Surrogate	Bone (170)	
ANT-COM	ANT-COM	Anterior Commissure	Brain	Surrogate	Nervous system (191-192)	
None	*ANUS*	*Anus (and Anal Canal)*	*LLI Wall*+	*Surrogate*	*Rectum (154)*	
AORTA	AORTA	Aorta	Muscle	Surrogate	Other Respiratory (160, 161, 163-165)	
APPENDX	APPENDX	Appendix	ULI Wall+	Surrogate	Colon (153)	
ART-TIS	ART-TIS	Arthritic Tissue	Bone Surface	Surrogate	Connective Tissue (171)	
ATRIAL	ATRIAL	Atrial Sarcoma	Muscle	Surrogate	Other Respiratory (160, 161, 163-165)	
BILE-D	BILE-D	Bile Duct	Liver	Surrogate	Gallbladder (156)	
BLDR	BLDR	Bladder	Urinary Bladder Wall	Surrogate	Bladder (188)	
BLOOD	BLOOD	Blood	Red Marrow	Surrogate	Leukemia (204-208)	
BON-MR	BON-MR	Bone Marrow	Red Marrow	FIIDOS	Leukemia (204-208)	
BON-P	BON-P	Bone (Pelvis)	Bone Surface	FIIDOS	Bone (170)	
BON-SR	BON-SR	Bone Surface	Bone Surface	FIIDOS	Bone (170)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
BONE	BONE	Bone	Bone Surface	FIIDOS	Bone (170)	
ELBOW	BON-EL	Bone (Elbow)	Bone Surface	FIIDOS	Bone (170)	
BRAIN	BRAIN	Brain	Brain	FIIDOS	Nervous System (191-192)	
BREAST	BREAST	Breast	Breast	FIIDOS	Breast (174-175)	
BRN-ST	BRN-ST	Brain Stem	Brain	Surrogate	Nervous system (191-192)	
None	*CECUM*	*Cecum*	*ULI Wall*$^{+}$	*Surrogate*	*Colon (153)*	
None	*CERVIX*	*Cervis*	*Uterus*	*Surrogate*	*Female Genitalia (179-182, 184)*	
CHOROID	CHOROID	Choroid	Brain	Surrogate	Eye (190)	
CL-LLI	CL-LLI	Colon (LLI)	LLI Wall^{+}	Surrogate	Colon (153)	
CL-ULI	CL-ULI	Colon (ULI)	ULI Wall^{+}	Surrogate	Colon (153)	
COLON	COLON	Colon	LLI Wall^{+}	Surrogate	Colon (153)	
CONTISS	CONTISS	Connective Tissue	Muscle	Tentative	Connective Tissue (171)	
CRNERV	CRNERV	Cranial Nerve	Brain	Surrogate	Nervous System (191-192)	
DEUDNM	DEUDNM	Duodenum	SI Wall^{+}	Surrogate	All Digestive (150-159)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
ENDOCR	ENDOCR	Endocrine Glands	Specific diseased organ must be known.	Endocrine organs are hypothalamus, pituitary, thyroid, parathyroid, adrenals, pineal body, ovaries, and testes plus pancreas. Select the specific organ if listed elsewhere in table; otherwise select "endocrine organs other than thyroid (code 194).		
ENDOS	ENDOS	Endosteum	Bone Surface	Surrogate	Bone (170)	
EPIG	EPIG	Epiglottis	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
ESOPH	ESOPH	Esophagus	ET Region+	FIIDOS	Esophagus (150)	
EYE	EYE	Eye	Brain	Surrogate	Eye (190)	
EYE-MUS	EYE-MUS	Eye (Muscle)	Muscle	Surrogate	Cancers of other and ill-defined sites (195)	
EYE-RET	EYE-RET	Eye (Retina)	Brain	Surrogate	Eye (190)	
EYELIDM	EYELIDM	Eyelid Muscle	Muscle	Surrogate	Cancers of Other and Ill-Defined Sites (195)	
FEMUR	BON-FMR	Bone (Femur)	Bone Surface	FIIDOS	Bone (170)	
GAL-BD	GAL-BD	Gallbladder	Liver	Surrogate	Gallbladder (156)	
GLOTTIS	GLOTTIS	Glottis	ET Region+	Surrogate	Other Respiratory (160, 161, 163-165)	
GUM	GUM	Gum	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
HEART	HEART	Heart	Muscle	Surrogate	Other Respiratory (160, 161, 163-165)	
None	*HYPPHR*	*Hypopharynx*	*ET Region*[+]	*Surrogate*	*Oral Cavity and Pharynx (140-149)*	
JAW	BON-JAW	Bone (Jaw)	Bone Surface	Surrogate	Bone (170)	
JOINTS	JOINTS	Joints	Bone Surface	Surrogate	Bone (170)	
KIDNEY	KIDNEY	Kidneys	Kidney	FIIDOS	Urinary Organs, excluding Bladder (189)	
None	*BON-HND*	*Bone (Hand)*	*Bone Surface*	*Surrogate*	*Bone (170)*	
L-INTES	L-INTES	Large Intestine	LLI Wall[+]	FIIDOS	Colon (153)	
LARYNX	LARYNX	Larynx	ET Region[+]	Surrogate	Other Respiratory (160, 161, 163-165)	
LEUK	LEUK	Leukemia	Red Marrow	Surrogate	Leukemia (204-208)	
None	*LIP*	*Lip*	*ET Region*[+]	*Surrogate*	*Oral Cavity and Pharynx (140-149)*	
LIPOMA	LIPOMA	Lipoma	Muscle	Surrogate	N/A	Not a malignant neoplasm
LIVER	LIVER	Liver	Liver	FIIDOS	Liver (155)	
LLI	LLI	Lower Large Intestine	LLI Wall	FIIDOS	Colon (153)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
LUNG	LUNG	Lungs	Lung	FIIDOS	Lung (162)	
LYMP-G	LYMP-G	Lymph Gland	Thymus	Surrogate	Lymphoma and Multiple Myeloma (200-203)	If this is primary disease
LYMP-N	LYMP-N	Lymph Nodes	Thymus	Surrogate	Lymphoma and Multiple Myeloma (200-203)	If this is primary disease
LYMPHO	LYMPHO	Lymphoma	Thymus	Surrogate	Lymphoma and Multiple Myeloma (200-203)	If this is primary disease
LYMPTS	LYMPTS	Lymphatic Tissue	Thymus	Surrogate	Lymphoma and Multiple Myeloma (200-203)	If this is primary disease
LYMSYS	LYMSYS	Lymph System	Thymus	Surrogate	Lymphoma and Multiple Myeloma (200-203)	If this is primary disease
None	*MIDEAR*	*Middle Ear*	*Brain*	*Surrogate*	*Other Respiratory (160, 161, 163-165)*	
MOUTH	MOUTH	Mouth	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
MUS-PC	MUS-PC	Muscle Peritoneal Cavity	Muscle	Surrogate	All Digestive (150-159)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
MUSCLE	MUSCLE	Muscle	Muscle	FIIDOS	Cancers of Other and Ill-Defined Sites (195)	
None	*NASCAV*	*Nasal Cavities*	*ET Region*[+]	*Surrogate*	*Other Respiratory (160, 161, 163-165)*	
NASALT	NASALT	Nasal Tip	ET Region[+]	Surrogate	Oral Cavity and Pharynx (140-149)	Specific disease needed if not skin cancer
NASO-LF	NASO-LF	Nasolabial Fold	ET Region[+]	Surrogate	Oral Cavity and Pharynx (140-149)	Specific disease needed if not skin cancer
NASOP	NASOP	Nasopharynx	ET Region[+]	Surrogate	Oral Cavity and Pharynx (140-149)	
NEROEND	NEROEND	Neuroendocrine System	Brain	Surrogate	Other Endocrine Glands (194)	
NRV-MUS	NRV-MUS	Neuro-Muscular	Muscle	Surrogate	Cancers of Other and Ill-Defined Sites (195)	
NRVSYS	NRVSYS	Nervous System	Brain	Surrogate	Nervous System (191-192)	
ORALCAV	ORALCAV	Oral Cavity	ET Region[+]	Surrogate	Oral Cavity and Pharynx (140-149)	
OROPHAR	OROPHAR	Oropharynx	ET Region[+]	Surrogate	Oral Cavity and Pharynx (140-149)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
None	*OVARY*	*Ovary*	*Ovary*	*FIIDOS*	*Ovary (183)*	
P-THYR	P-THYR	Parathyroid	Thyroid	Surrogate	Other endocrine Glands (194)	
PALATE	PALATE	Palate	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
PANCRS	PANCRS	Pancreas	Pancreas	FIIDOS	Pancreas (157)	
PAROTID	PAROTID	Parotid Gland	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
PENIS	PENIS	Penis	Testes	Surrogate	All Male Genitalia (185-187)	
PRTNM	*PRTNM*	*Peritoneum*	*Muscle*	*Surrogate*	*Cancers of Other and Ill-Defined Sites (195)*	
PHAR	PHAR	Pharynx	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
None	*PNLGL*	*Pineal Gland*	*Brain*	*Surrogate*	*Other Endocrine Glands (194)*	
PITTGL	PITTGL	Pituitary Gland	Brain	Surrogate	Other Endocrine Glands (194)	
None	*PLEURA*	*Pleura*	*Lung*	*Surrogate*	*Other Respiratory (160, 161, 163-165)*	
PROSTA	PROSTA	Prostate	Testes	Surrogate	All Male Genitalia (185-187)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
RD-MRW	RD-MRW	Red Marrow	Red Marrow	FIIDOS	Leukemia (204-208)	
RECTUM	RECTUM	Rectum	LLI Wall+	Surrogate	Rectum (154)	
RESPOTH	RESPOTH	Respiratory other than Lung	ET Region+	Surrogate	Other Respiratory (160, 161, 163-165)	
SAL-GLS	SAL-GLS	Salivary Glands	ET Region+	FIIDOS	Oral Cavity and Pharynx (140-149)	
SCROTUM	SCROTUM	Scrotum	Testes	Surrogate	All Male genitalia (185-187)	
SHLDR	BON-SHLDR	Bone (Shoulder)	Bone Surface	Surrogate	Bone (170)	If bone cancer
SINSMX	SINSMX	Sinus (Maxillary)	ET Region+	Surrogate	Other Respiratory (160, 161, 163-165)	
SINSNA	SINSNA	Sinus (Nasal)	ET Region+	Surrogate	Other Respiratory (160, 161, 163-165)	
SINUS	SINUS	Sinus	ET Region+	Surrogate	Other Respiratory (160, 161, 163-165)	
SMINST	SMINST	Small Intestine	SI Wall+	FIIDOS	All Digestive (150-159)	
SOFTH	ST-TH	Soft Tissue (Thigh)	Muscle	Surrogate	Cancers of Other and Ill-Defined Sites (195)	
SP-CRD	SP-CRD	Spinal Cord	Brain	Surrogate	Nervous System (191-192)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
SPINE	BON-SPINE	Bone (Spine)	Bone Surface	Surrogate	Bone (170)	Cancer of vertebrae
SPLEEN	SPLEEN	Spleen	Spleen	FIIDOS	Cancers of Other and Ill-Defined Sites (195)	Use only if solid cancer of spleen is the primary disease
SPN-NV	SPN-NV	Spine Nerves	Brain	Surrogate	Nervous System (191-192)	
ST-ARM	ST-ARM	Soft Tissue Upper Arm	Muscle	Surrogate	Cancers of Other and Ill-Defined Sites (195)	
ST-HIP	ST-HIP	Soft Tissue Hip	Muscle	Surrogate	Cancers of Other and Ill-Defined Sites (195)	
ST-SHLD	ST-SHLD	Soft Tissue Shoulder	Muscle	Surrogate	Cancers of Other and Ill-Defined Sites (195)	
STMACH	STMACH	Stomach	Stomach Wall	FIIDOS	Stomach (151)	
TESTES	TESTES	Testes	Testes	FIIDOS	All Male Genitalia (185-187)	
THROAT	THROAT	Throat	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
THYMUS	THYMUS	Thymus	Thymus	FIIDOS	Other Respiratory (160, 161, 163-165)	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
THYMUSC	THYMUSC	Thigh Muscle	Muscle	FIIDOS	Cancers of Other and Ill-Defined Sites (195)	
THYROD	THYROD	Thyroid	Thyroid	FIIDOS	Thyroid (193)	
TONGUE	TONGUE	Tongue	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
TONSILS	TONSILS	Tonsils	ET Region+	Surrogate	Oral Cavity and Pharynx (140-149)	
TRACHEA	TRACHEA	Trachea	Lung	Surrogate	Lung (162)	
U-BLDDR	U-BLDDR	Urinary Bladder	Urinary Bladder Wall	FIIDOS	Bladder (188)	
U-TRCT	U-TRCT	Urinary Tract	Urinary Bladder Wall	FIIDOS	Urinary Organs, Excluding Bladder (189)	
ULI	ULI	Upper Large Intestine	ULI Wall+	FIIDOS	Colon (153)	
URTHRA	URTHRA	Urethra	Urinary Bladder Wall	Surrogate	Urinary Organs, Excluding Bladder (189)	
None	*URTR*	*Ureter*	*Urinary Bladder Wall*	*Surrogate*	*Urinary Organs, Excluding Bladder (189)*	

Table A-1. Cross-Reference List of NTPR NuTRIS Codes, NTPR Standard Organs, and NIOSH-IREP Cancer Models (cont.)

(Italicized rows are proposed additions)

Current NuTRIS Organ Code	Proposed NuTRIS Organ Code	Description	NTPR Standard Organ	Surrogate Type†	NIOSH-IREP Cancer Model (ICD-9)	Comments
None	*UVL*	*Uvula*	*ET Region*[+]	*Surrogate*	*Oral Cavity and Pharynx (140-149)*	
VOCRD	VOCRD	Vocal Cords	ET Region[+]	Surrogate	Other Respiratory (160, 161, 163-165)	
YELMAR	YL-MAR	Yellow Marrow	Red Marrow	Surrogate	Leukemia (204-208)	

[+] ET=extra-thoracic, LLI=lower large intestine, SI=small intestine, ULI = upper large intestine.

† FIIDOS means that there is a dose conversion factor for the organ. Surrogate means that a dose conversion factor for the NTPR Standard organ is used for the diseased organ.

Appendix B.

Proposed NTPR Expedited Processing Groups

B-1 Highest-Dose Cohort

Expedited Processing Groups (EPGs) are listed in Table B-4 to Table B-13 for participants in test operations conducted in the Pacific Proving Ground, in Table B-14 for participants in test operations conducted at the Nevada Test Site, and in Table B-15 for individuals who were residents of Enewetak Atoll during post-operational periods. In these tables, the column labeled "Highest-Dose Cohort External Residual Gamma Dose" includes doses previously assessed and documented in the publications referred to as NTPR White Books, Blue Books or other technical reports. These doses are not the proposed expedited doses. They do, however, help identify the cohort receiving the highest external gamma dose from residual radioactive material. The schedules and activities of the "highest-dose cohort" are used as a starting point for a scenario of participation and radiation exposure for an EPG. Refer to Section 3 of this report for a definition the "high-dose cohort."

B-2 Treatment of Exclusions

NTPR participants are excluded from an EPG if they had the potential for higher doses than the EPG or if there is insufficient information regarding their activities. One or more cohorts having well-characterized, common activities may be organized into a separate EPG. Cohorts are organized into separate EPGs if their overall exposure is deemed distinct from the members of the EPG.

Participants or cohorts excluded from EPGs based on operational activities that are specific to the group are shown in the column labeled "Exclusions (Units, cohorts, activities, etc.)" These exclusions are either organized as a separate EPG or identified for further case-specific review and, possibly a full RDA. Personnel and activities to be excluded are grouped into three general categories of participation as listed in Table B-1 to Table B-3. These exclusions apply unless otherwise stated for a specific EPG as described in the Compendium of EPGs (DTRA, 2011).

Table B-1. General Exclusions 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
Either consumption of meals while topside, or being topside during episodes of descending fallout
Individuals with film badge records and whose total film badge dose is greater than the EPG external dose determined for their respective EPG

* These exclusions apply unless otherwise stated for a specific EPG as described in the Compendium of Proposed EPGs (DTRA, 2011).

Table B-2. General Exclusions Applicable to Pacific Proving Ground Land-Based Personnel*

Activity or Cohort
Participation in more than one testing 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 as Bikini Resurvey personnel in 1947)
Personnel whose regular assignment was to a Radiological Safety (Rad-Safe) unit
Flight drone or sounding rocket operations
Excursion to any test island
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 EPG external dose determined for their respective EPG

* These exclusions apply unless otherwise stated for a specific EPG as described in the Compendium of Proposed EPGs (DTRA, 2011).

Table B-3. General Exclusions Applicable to Participants during Testing at the Nevada Test Site*

Activity or Cohort
Participation in more than one testing 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)
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

* These exclusions apply unless otherwise stated for a specific EPG as described in the Compendium of Proposed EPGs (DTRA, 2011).

Table B-4. Proposed Expedited Processing Groups for Operation CROSSROADS (1946)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
CROSSROADS Support Ship-Based Personnel	Crews of CROSSROADS support ships (those included in Weitz et al., 1982b), and crews of the re-manned target ships USS BLADEN, USS CORTLAND, USS FILLMORE, USS GENEVA, USS NIAGARA, and USS LCI(L)615.	• Target ship boardings after BAKER (distinct EPG, see below). • Flight/drone operations aboard USS SHANGRI-LA and USS SAIDOR. • USS BRUSH (distinct EPG, see below). • Ammunition Disposal Units at Kwajalein (Post-XRD). • Bikini resurvey (distinct EPG, see below). • Crew member of the USS ACHOMAWI, USS COUCAL, and USS O'BRIEN.	USS RECLAIMER†	1.7 (Weitz et al., 1982a , Table 7-1)	30,000

Table B-4. Proposed Expedited Processing Groups for Operation CROSSROADS (1946) (cont.)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
CROSSROADS Land-Based Personnel	Land-based personnel at Kwajalein and Enewetak Atolls and weather station islands (there were no land-based personnel at Bikini Atoll).	• Decontamination of target ships moored at Kwajalein Island. • Towing of target ships to Kwajalein Island. • Small boat operations involving contaminated target or support ships moored at Kwajalein Island. • Performing surveys, construction, or experiments on Bikini Atoll after Shot ABLE. • Unloading, inspecting, handling, moving, and decontaminating ammunition on target ships moored at Kwajalein Island. • Handling of contaminated clothing, waste, or equipment created during ammunition inspection and unloading operations at Kwajalein Island.	Army Air Group TG 1.5	0.1 (DTRA, 2008, Appendix B-1, Operation CROSSROADS)	2,600

Table B-4. Proposed Expedited Processing Groups for Operation CROSSROADS (1946) (cont.)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
CROSSROADS Target Ship-Based Personnel	Crews that boarded contaminated target ships after Shot BAKER.	• Crews of six re-manned 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 Crew EPG. • Crew members of any target ships who were subsequently assigned to Ammunition Disposal Units and participated in ammunition unloading at Kwajalein. • Personnel who were crew members of target submarines.	USS CARTERET	2.9 (previous RDA)	8,000

Table B-4. Proposed Expedited Processing Groups for Operation CROSSROADS (1946) (cont.)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
USS BRUSH Crew (February 25-27, 1947)	Crew of USS BRUSH in Kwajalein Lagoon, February 1947.	• Personnel who transferred to USS BRUSH after the ship's departure from Kwajalein Atoll on February 27, 1947.	Crew members who participated in excursions to target ships.	0.07 (previous RDA)	250
Bikini Resurvey Personnel July-August 1947	Crew members of USS CHILTON, USS COUCAL and LCI(L) 615 who participated as members of the Bikini Resurvey team in July and August 1947.	• None specific to this group.	Navy Construction Battalion Detachment 1800.	0.8 (previous RDA)	700

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† Crews of USS O'BRIEN received limited fallout after ABLE, in addition to BAKER's. The corresponding external dose when added to that due to exposure to BAKER fallout is smaller than that for the USS RECLAIMER. USS ACHOMAWI and possibly other support ships had faulty evaporators that may have resulted in an additional internal dose due to ingestion of contaminated drinking water.

‡ These are not assigned doses to members of EPGs (see introductory narrative of this appendix).

Table B-5. Proposed Expedited Processing Groups for Operation SANDSTONE (1948)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
SANDSTONE Ship-Based Personnel	Personnel on ships during Operation SANDSTONE to include transient ships.	• Individuals who participated in Enewetak and Bikini Atoll resurveys (Post-SANDSTONE). • 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.	USS HENRY W. TUCKER	0.05 (DTRA, 2008, Appendix B-2, Operation SANDSTONE)	6,400
SANDSTONE Land-Based Personnel	Army, Navy, and Air Force personnel stationed at Enewetak and Kwajalein Atolls.	• Individuals who participated in Enewetak and Bikini Atoll resurveys (Post-SANDSTONE). • 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 were stationed at Majuro Atoll, Rongerik Atoll, or Wake Island.	TG 7.4 (Air Force) at Kwajalein Atoll	0.08 (DTRA, 2008, Appendix B-2, Operation SANDSTONE)	5000

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-6. Proposed Expedited Processing Groups for Operation GREENHOUSE (1951)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
GREENHOUSE Ship-Based Personnel	Personnel on ships during Operation GREENHOUSE including transient ships.	• No specific exclusions.	USNS SGT. C. E. MOWER	0.68 (DTRA, 2008, Appendix B-3, Operation GREENHOUSE)	4,700
GREENHOUSE Land-Based Personnel	Army, Navy, and Air Force personnel stationed at Enewetak Atoll, Kwajalein Atoll, and weather station islands.	• Individuals who participated in clothing contamination tests.	Headquarter, Joint Task Force-3	3.1 (DTRA, 2008, Appendix B-3, Operation GREENHOUSE)	4,700

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-7. Proposed Expedited Processing Groups for Operation IVY (1952)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
IVY Ship-Based Personnel	Personnel on ships during Operation IVY including transient ships.	• None specific to this group.	USS LIPAN	0.036 (DTRA, 2008, Appendix B-4, Operation IVY)	4,700
IVY Land-Based Personnel	Army, Navy, and Air Force personnel stationed at the residence islands of Enewetak Atoll, Kwajalein Atoll, and weather station islands.	• None specific to this group.	7126th Army Unit on Enewetak Atoll.	0.059 (DTRA, 2008, Appendix B-4, Operation IVY)	4,700

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-8. Proposed Expedited Processing Groups for Operation CASTLE (1954)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
CASTLE High-Dose Ship-Based Personnel	Personnel on Operation CASTLE ships that received heavier fallout.	• Personnel on Operation CASTLE ships that received light fallout to include transient ships (distinct EPG, see below). • 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).	USS PHILIP (average crew)	3.56 (DTRA, 2008, Appendix B-5, Operation CASTLE)	1350
CASTLE Low-Dose Ship-Based Personnel	Personnel on ships at Operation CASTLE that received light fallout and transient ships.	• Personnel on Operation CASTLE ships that received heavy fallout (distinct EPG, see above). • Shore excursions on Rongelap or Rongerik Atolls. • Were crew members of YAG 39 (USS GEORGE EASTMAN), USS PATAPSCO (AOG 1), or YAG 40 (GRANVILLE S. HALL).	USS ESTES	1.76 (DTRA, 2008, Appendix B-5, Operation CASTLE)	4,300
CASTLE Land-Based Personnel	Army, Navy, and Air Force personnel stationed at Enewetak Atoll, Kwajalein Atoll, and weather station islands.	• Excursions on Rongelap or Rongerik Atolls.	7126th Army Unit stationed at Enewetak Island	1.09 (DTRA, 2008, Appendix B-5, Operation CASTLE)	2,600

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-9. Proposed Expedited Processing Group for Operation WIGWAM (1955)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
WIGWAM Ship-Based Personnel	All participants.	• Individuals who performed large scale ship decontamination.	USS CHANTICLEER	0.13 (DTRA, 2008, Appendix B-6 Operation WIGWAM)	6,200

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-10. Proposed Expedited Processing Groups for Operation REDWING (1956)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
REDWING Ship-Based Personnel	Military personnel who were assigned to a ship that participated in Operation REDWING activities including transient ships.	• None specific to this group.	USS SILVERSTEIN	1.4 (DTRA, 2008, Appendix B-7, Operation REDWING)	est. 6,000
REDWING Land-Based Personnel	Military personnel who supported Operation REDWING and resided on Enewetak Atoll, Kwajalein Atoll, or weather station islands during Operation REDWING.	• None specific to this group.	7126th Army Unit	3.6 (DTRA, 2008, Appendix B-7, Operation REDWING)	4,000

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-11. Proposed Expedited Processing Groups for Operation HARDTACK I (1958)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
HARDTACK I Ship-Based Personnel	Personnel on ships at Operation HARDTACK I including transient ships.	• Crew Members of ships that only participated in shots at Johnston Island (distinct EPG, see below). • Crew Members of ships that served as unmanned target vessels for the underwater shots WAHOO and UMBRELLA to include three destroyers (KILLEN, HOWORTH, and FULLAM), a liberty ship (SS MICHAEL MORAN), and a submarine (BONITA).	USS ARIKARA	0.8 (DTRA, 2008, Appendix B-8, Operation HARDTACK I)	6,000
HARDTACK I Non-exposed Ship-Based Personnel	All ships that only participated in Shots at Johnston Atoll.	• Individuals with non-zero film badge doses.	USS EPPERSON (DDE-719)	NPE† (DTRA, 2008, Appendix B-8, Operation HARDTACK I)	1,000
HARDTACK I Land-Based Personnel	Personnel resident on Parry and Enewetak Islands of Enewetak Atoll and Eneu Island of Bikini Atoll.	• Personnel who resided on Japtan Island during the operation. • Personnel assigned to Johnston Island.	TG 7.1 (Scientific Group stationed on Parry Island)	1.9 (DTRA, 2008, Appendix B-8, Operation HARDTACK I)	3,500

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† NPE stands for no potential for exposure.

‡ These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-12. Proposed Expedited Processing Groups for Operation ARGUS (1958)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
ARGUS Ship-Based Personnel	All participants in ARGUS.	• None specific to this group.		NPE† (DTRA, 2008, Appendix B-9 ARGUS)	4,369

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† NPE stands for no potential for exposure.

‡ These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-13. Proposed Expedited Processing Groups for Operation DOMINIC I (1962)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)‡	Number of Participants (Approx.)
DOMINIC I Personnel	All participants in DOMINIC I.	• Crewmembers of USS SIOUX (ATF 75), USC&GSS PIONEER (OSS-31), and USS MONTICELLO (LSD-35) during Shot SWORDFISH. • Personnel involved in the recovery/handling of radioactively contaminated instrumented pods and rocket nose cones associated with successful THOR missile and rocket launches. • Personnel involved in recovery and decontamination operations after any of the THOR missile incidents during Shots BLUEGILL, STARFISH, BLUEGILL PRIME. • Personnel involved in recovery, servicing, or boarding of target rafts after airdrop shots. • Personnel involved in the recovery and handling of other contaminated with radioactive materials due to neutron activation.	N/A	NPE† (DTRA, 2008, Appendix B-10 DOMINIC I)	25,000

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† NPE stands for no potential for exposure.

‡ These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-14. Proposed Expedited Processing Groups for Nevada Test Site (NTS)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)§	Number of Participants (Approx.)
NTS Observer and Maneuver Troops, 1951–1962	Personnel that participated as a member of ground-based official EDR observer groups or maneuver groups during NTS shots from 1951 through 1962, including Exercise IVY FLATS at DOMINIC II. Members of 505th Military Police Battalion that performed traffic control or march guide activities during UPSHOT-KNOTHOLE (1953) or TEAPOT (1955).	• Individuals who participated in one of the Volunteer Observer Programs conducted during some of the test series. • Any individuals who participated in more than one maneuver group at more than one shot. • The following maneuver groups are excluded and are each evaluated as a distinct EPG: - The 2nd MCPAEB at Operation UPSHOT-KNOTHOLE, Shot BADGER - Task Force WARRIOR at Operation PLUMBBOB, Shot SMOKY.	UPSHOT-KNOTHOLE SIMON BCT-A	3.2 (DTRA, 2008, Appendices C-3 to C-7)	42,600
NTS Participants with no Forward Area Activities, 1951–1962	Support personnel stationed at Camp Desert Rock, Camp Mercury, Indian Springs Air Force Base, or Nellis Air Force Base during any single operation from 1951 through 1962 who did not conduct any activities in any NTS forward area. Inter-operational personnel at CDR, Camp Mercury, and Indian Springs Air Force Base.	• None specific for this group.	UPSHOT-KNOTHOLE CDR support troops	0.02 (DTRA, 2008, Appendices C-3 to C-7; various NTPR technical memos)	Unknown

Table B-14. Proposed Expedited Processing Groups for Nevada Test Site (NTS) (cont.)

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)§	Number of Participants (Approx.)
Operation UPSHOT-KNOTHOLE 2nd Marine Corps Provisional Atomic Exercise Brigade (2MCPAEB)	Marines that participated in the maneuver at UPSHOT-KNOTHOLE Shot BADGER (1953).	• 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.	2nd MCPAEB HQ‡	3.7 (DTRA, 2008, Appendix C-5)	2,167
Operation PLUMBBOB Task Force WARRIOR (TFW)	Army infantry troop test Task Force WARRIOR conducted at PLUMBBOB Shot SMOKY (1957).	• Canadian Army Platoon (7th Platoon, Queen's Own Rifles). • 3rd Transportation Battalion (Helicopter). • Personnel not in an element of Company C, 1st Battle Group whose activities are not encompassed by the TFW highest-dose cohort scenario.	2nd Platoon	0.7 (Goetz et al., 1979))	350

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

‡ Members of 1st Battalion 8th Marines of the 2nd MCPAEB received a higher total dose from external residual radiation (4.7 rem) than did the 2nd MCPAEB HQ personnel. However, no internal dose was accrued concurrently with approximately half of this total dose that was due to direct radiation from the BADGER stem as it passed the troops. Most of the dose to 2nd MCPAEB HQ personnel was from fallout, for which internal dose was concurrently accrued.

§ These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Table B-15. Proposed Expedited Processing Groups for PPG Post-Operations

Proposed EPG*	EPG Members	Exclusions (Units, cohorts, activities, etc.)	Highest-Dose Cohort	Estimated External Residual Gamma Dose for the Highest-Dose Cohort (rem)†	Number of Participants (Approx.)
Post-SANDSTONE Enewetak Atoll	Residents of Enewetak Atoll on the islands of Enewetak, Parry and Japtan.	• None specific for this group.	Residents of Enewetak Island	0.05 (Mason, 2009)	1,900
Post-GREENHOUSE Enewetak Atoll	Residents of Enewetak Atoll on the islands of Enewetak, Parry and Japtan.	• None specific for this group.	Residents of Parry Island	2.4 (Mason, 2009)	2,600
Post-IVY Enewetak Atoll	Residents of Enewetak Atoll on the islands of Enewetak, Parry and Japtan.	• None specific for this group.	Residents of Enewetak Island	0.028 (Mason, 2009)	600
Post-CASTLE Enewetak Atoll	Residents of Enewetak Atoll on the islands of Enewetak, Parry and Japtan.	• None specific for this group.	Residents of Enewetak Island	0.25 (Mason, 2009)	1,000
Post-REDWING Enewetak Atoll	Residents of Enewetak Atoll on the islands of Enewetak, Parry and Japtan.	• None specific for this group.	Residents of Parry Island	1.9 (Mason, 2009)	4,500
Post-HARDTACK I Enewetak Atoll	Residents of Enewetak Atoll on the islands of Enewetak and Parry.	• Individuals who resided on Japtan Island.	Residents of Enewetak Island	0.56 (Mason, 2009)	973

* Detailed descriptions with complete lists of ships, cohorts, excluded units, etc., are included in the EPG Compendium (DTRA, 2011).

† These are not assigned doses to members of EPGs (see the introductory narrative of this appendix).

Glossary

absorption type	A characterization of the rate at which material deposited in the respiratory tract is absorbed into the blood. Three material "types" to provide default absorption rates when empirically determined rates are unavailable. Types are defined for fast (F), moderate (M), and slow (S) absorption.
air delivery aircraft	In atmospheric nuclear testing, an aircraft that releases a test nuclear device from a specified altitude above a designated point on the ground; sometimes called an air drop aircraft.
alpha particle	A positively-charged particle ejected spontaneously from the nuclei of some radionuclides. It is identical to a helium nucleus (two protons and two neutrons) with a mass number of four and an electric charge of +2. It has low penetrating power and a short range (a few centimeters in air).
benefit of the doubt	A principle applied by the VA in adjudicating veteran's claims used to decide, all other conditions being equal, in favor of the claimant.
beta radiation	Radiation consisting of energetic electrons or positrons (positively charged electrons) emitted spontaneously from nuclei in decay of some radionuclides. Its penetrating power is more than an alpha particle but less than a gamma ray.
breathing rate	A parameter used in calculating a radiation dose from the inhalation of radioactive materials that represents the volume of air breathed in per unit of time; herein expressed as $m^3\ hr^{-1}$.
cancer risk model	A mathematical model that relates the probability that a cancer will occur in an organ to the radiation dose delivered to the organ; used to estimate probability of causation.
cloud-sampling aircraft	In atmospheric testing, aircraft that penetrate the cloud of debris generated by a nuclear detonation to monitor the radiation exposure rate at various locations in the cloud and to collect samples of the airborne material for further analysis.
cloud-tracking aircraft	In atmospheric nuclear testing, aircraft that follow the cloud of debris generated by a nuclear detonation by alternately engaging and then retreating from the edge of the cloud, often by observing radiation exposure rates.
cohort	A group of individuals having a common association or factor; for example, all members of a battalion combat team who did not perform any special duties.
dose coefficient	An organ and radionuclide specific factor for calculating the dose to an organ from a unit intake of radioactive material as recommended by the ICRP.

dose conversion factor	An organ and test shot specific factor for calculating the radiation dose from alpha particles and beta particles plus gamma rays due to radioactive materials deposited in the body during nuclear testing.
dose reconstruction	See *radiation dose assessment.*
dosimetry	The science or technique of determining dose from exposure to radiation.
DTRA-approved uncertainty factors	Multiplying factors applied to the total external dose (3) and internal dose (10) in deterministic RDAs to calculate an upper-bound dose for each.
equivalent dose	Mean absorbed dose in a tissue or organ ($D_{T,R}$) weighted by the radiation weighting factor (w_R) for the type and energy of radiation. For exposure from external sources, w_R applies to the radiation type and energy incident on the body. The SI unit of equivalent dose is J kg^{-1} with the special name sievert (Sv). 1 Sv = 1 J kg^{-1}. In legacy units as used in NTPR, 1 Sv = 100 rem.
exclusion	An activity involving radiation exposure that is judged to involve situations and radiation environments, which are not suitable for expedited processing of groups with routine duties.
Exercise Desert Rock	A series of activities conducted at the NTS to provide training for military personnel in the effects of nuclear detonations.
expedited processing	An approach to determining the radiation dose for a claimant in the NTPR program using methods, which tend to overestimate actual doses to allow more timely and efficient completion of cases while providing benefit of the doubt.
expedited processing group	A group of military participants in an atmospheric nuclear test or tests who performed similar types of activities, encountered similar radiation environments, and whose radiation doses were similar.
exposure	A general term used to describe the act of being exposed to ionizing radiation. Exposure is also a defined ionizing radiation quantity that is a measure of the ionization produced in air. The unit of exposure is coulomb per kilogram (C kg^{-1}). A special name for exposure is Roentgen (R), where 1 R = 2.58×10^{-4} C kg^{-1}.
exposure parameter	A variable of set of variables in a mathematical model or dose calculation method; such as exposure rate.
exposure rate	The quantity of exposure produced per unit time (e.g., C kg^{-1} hr^{-1}, R hr^{-1}).
exposure scenario	A description of the radiation environment at locations and times of exposure and the activities of individuals during that time.
fallout	The radioactive material falling from the atmosphere to the ground after a nuclear event, such as a detonation.

fallout deposition	The process of fallout collecting on the ground.
film badge	A device consisting of unexposed photographic film and various absorbing materials (filters) in a holder and worn by a person or placed in a location to measure ionizing radiation. When the film is developed the radiation dose and type of radiation may be determined.
flight drone operation	Activities involving remotely controlled aircraft during nuclear test operations; for example in cloud sampling.
gamma radiation	Electromagnetic radiation emitted by an atomic nucleus during the process of transition or radioactive decay. Gamma rays are much more penetrating than alpha and beta particles.
heliborne operations	The collection of activities in and around operating helicopters, which can resuspend radioactive contamination on ground surfaces.
highest-dose cohort	A cohort of participants at specific test operation that has the highest external dose from residual gamma radiation of all cohorts considered for inclusion in an EPG.
initial radiation	Ionizing radiation emitted within the first minute following a nuclear detonation; primarily consists of neutrons and gamma radiation.
internally-deposited	Radioactive material that remains in the body after entry by inhalation, ingestion, or through breaks in the skin and may be distributed to various bodily organs and tissues.
inter-operational personnel	Participants who were present at the locations of atmospheric test operations during periods, which are not within the officially specified dates for the operation.
isotope	One of several nuclides of a chemical element having the same number of protons in their nuclei, but different nuclear mass numbers due to different numbers of neutrons in the nucleus. An element may have numerous stable or unstable (radioactive) isotopes.
limiting dose	A quantity of radiation dose that produces a PC of 40 percent for a specific cancer calculated assuming exposure at age 18 and diagnosis of disease generally at age 50.
maneuver troop	A military participant in an atmospheric nuclear test or tests who was involved in post-shot, military-type maneuvers.
maximized	In the context of this report, the modifications to a basic scenario of exposure and its dose calculation parameters that increase the estimated dose.
mean dose	The arithmetic average of a set of dose values determined by dividing the sum of the values by the number of values.
neutron	An uncharged elementary particle having a mass slightly greater

	than a proton that is usually stable when inside a nucleus but unstable when outside
neutron activation	The formation of a radionuclide produced by the absorption of a neutron by the nucleus of a given nuclide; e.g., the production of ^{60}Co through absorption of a neutron by ^{59}Co.
non-exposed ships	Ships that participated in an operation in the PPG whose personnel had no potential for exposure to radiation.
NTPR blue book	One of a series of reports produced by the Defense Nuclear Agency (a predecessor of DTRA) that describes the general details, events, personnel participation, and radiation doses for a specific test operation or portion of one.
NTPR NuTris Organ Code	An item in the data dictionary of the Nuclear Test Review Information System used to code the organ or disease that is the basis of a claim to the VA.
NTPR Standard Organ	A term used to refer to one of the 23 organs for which published ICRP dose coefficients are available for the calculation of radiation dose to organs and tissues from the intake of radioactive material.
NTPR Surrogate	A term used to specify which of the 23 NTPR Standard Organs are chosen for calculation of the radiation dose for other organs; e.g. the testes is used as the NTPR Surrogate for the prostate in claims for cancer of the prostate.
NTPR White Book	One of a series of reports produced by the Defense Nuclear Agency (a predecessor of DTRA) that documents the radiation dose assessment for a particular unit or collection of similar units who participated in the atmospheric nuclear test program.
observer troop	A military member who was present as a member of a group to observe a specific atmospheric nuclear test but who did not perform any military maneuver-type activities (generally used only for NTS observers).
operation	In the context of this report, a series of nuclear tests conducted at a specified location and within a specified time period, typically within a single calendar year; e.g. Operation CROSSROADS.
participant	A veteran who was present at the location and within the defined time period of any atmospheric nuclear test series, or operation.
probability of causation	The probability that a specific disease in a person was caused by their exposure to a hazardous agent, such as ionizing radiation. For purposes of this report, probability of causation is calculated for specific cancers using the NIOSH-IREP computer software.
radiation dose assessment	An estimation of radiation doses received by a specified individual or individuals under specified exposure conditions. In NTPR, a full RDA includes consideration of all input received from the

	participant.
rem	The special name for the conventional unit of equivalent dose; 1 rem = 0.01 Sv.
residence islands	Islands in the Enewetak Atoll that were located at a distance from the test islands and generally served as the location where most participants were billeted and worked.
residual radiation	Beta and gamma radiation other than initial radiation, which is emitted by fallout and neutron activation products following a nuclear detonation. This was a common source of exposure for NTPR program participants.
scenario of exposure	See *exposure scenario.*
screening dose	The quantity of radiation dose that produces a PC of 50 percent for a specific cancer calculated for this report assuming exposure at age 18 and diagnosis of disease generally at age 50.
service observer	See *observer troop.*
service-connected disability	A term that VA uses to describe whether a veteran's medical condition or disability is related to his active military service.
shore excursion	Occasions when ship-board personnel may have gone ashore on islands for liberty or to support test operations.
sounding rocket operation	Participants involved with the recovery of sounding rockets that may have penetrated the nuclear cloud during tests.
test series	Synonymous with *operation.*
topside	Aboard ship, this is the weather deck of topmost deck; as in the seaman was topside during observation of Shot BRAVO.
upper bound	A property of a measured or calculated quantity that indicates the highest value of a range of values and represents a certain level of confidence or credibility that the value would not be exceeded by more than a certain percentage; e.g., the upper bound dose at 95 percent.
volunteer observers	Military participants at certain nuclear tests conducted at the NTS, who viewed detonations at distances from ground zero that were closer than other observers and that could involve significant dose.

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Abbreviations, Acronyms, and Symbols

α	Alpha (radiation)
β+γ	Beta and Gamma (radiation)
2MCPAEB	2nd Marine Corps Provisional Atomic Exercise Brigade
AEC	Atomic Energy Commission
AFB	Air Force Base
ALL	Acute Lymphocytic Leukemia
Am-241	Americium-241
AML	Acute Myeloid Leukemia
ATSDR	Agency for Toxic Substances and Disease Registry
BCT-A	Battalion Combat Team Able
BEIR	Biological Effects of Ionizing Radiation
CDC	Centers for Disease Control and Prevention
CDC-CMMS	CDC and the Centers for Medicare and Medicaid Services
CDR	Camp Desert Rock
CFR	Code of Federal Regulations
CLL	Chronic Lymphocytic Leukemia
Cm-242	Curium-242
CML	Chronic Myeloid Leukemia
CMMS	Centers for Medicare and Medicaid Services
CONUS	Continental United States
DoD	Department of Defense
DTRA	Defense Threat Reduction Agency
E	Energy
EDR	Exercise Desert Rock
EEOICPA	Energy Employees' Occupational Injury Compensation Program Act
EPG	Expedited Processing Group
ET	Extra Thoracic
Ext Dose	External Dose
F	Type F (Fast rate of absorption)
FIIDOS	Fallout Inhalation and Ingestion Dose to Organs
ICD-9	International Statistical Classification of Diseases and Related Health Problems (9th Edition)
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron volt
LLI	Lower Large Intestine

m^3 hr^{-1}	cubic meters per hour
M	Type M (moderate rate of absorption)
MeV	megaelectron volt
MPB	Military Police Battalion
N/A	Not Applicable
NAS	National Academy of Science
NCI	National Cancer Institute
NIH	National Institutes of Health
NIOSH	National Institute of Occupational Safety and Health
NIOSH-IREP	National Institute of Occupational Safety and Health-Interactive RadioEpidemiological Program
Np-237	Neptunium-237
NPE	No Potential for Exposure
NRC	National Research Council
NTPR	Nuclear Test Personnel Review
NTS	Nevada Test Site
NuTRIS	Nuclear Test Review Information System
OBS/Man	Observer/Maneuver
OPHEH	Office of Public Health and Environmental Hazards
ORAU	Oak Ridge Associated Universities
PC	Probability of Causation
PPG	Pacific Proving Ground
Pu-238	Plutonium-238
Pu-239	Plutonium-239
Pu-240	Plutonium-240
Rad-Safe	Radiological Safety
RDA	Radiation Dose Assessment
rem	Roentgen Equivalent Man
S	Type S (slow rate of absorption)
SC-1	VBDR Subcommittee 1 on DTRA Dose Reconstruction Procedures
SD	Screening Dose
SI	Small Intestine
SM	Standard Method
SOP	Standard Operating Procedure
TFBB	Task Force BIG BANG
TFW	Task Force WARRIOR
TG	Task Group
U-235	Uranium-235
U-238	Uranium-238
UB	Upper Bound
ULI	Upper Large Intestine

USDOE	United States Department of Energy
USNS	United States Naval Ship
USS	United States Ship
VA	United States Department of Veterans Affairs
VBDR	Veterans' Advisory Board on Dose Reconstruction
XRD, XRDS	Operation CROSSROADS
YAG	Yard Auxiliary, General (Miscellaneous Auxiliary Service Craft)

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