<table>
<tr><td>Office of Compensation Analysis and Support

Technical Information Bulletin</td><td colspan="2">Document Number:
OCAS-TIB-0010
Effective Date: 12/30/2005
Revision No. 2</td></tr>
<tr><td colspan="2">Best Estimate External Dose Reconstruction for Glovebox Workers</td><td>Page 1 of 14</td></tr>
<tr><td colspan="2">Approval: <u>Signature on File</u> Date: <u>12/22/2005</u>
J.W. Neton, Associate Director for Science</td><td>Supersedes:
Rev. 01</td></tr>
</table>

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
5/18/2005	5/18/2005	1	Updated document to provide methodology and guidance on applying correction factors to glove box workers for over and under estimation of dose.
12/30/2005	12/30/2005	02	Modified to provide best estimate approach

1.0 Purpose

The purpose of this technical information bulletin (TIB) is to provide guidance on dose reconstructions for glovebox workers. This TIB discusses the special exposure characteristics that may be encountered by energy employees who work with gloveboxes and provides special dose correction factors or modifiers that should be applied to affected energy employee's dose. It should be noted that throughout this technical information bulletin, the term glovebox is used, however, in the early years of the Atomic Energy Commission (AEC) facilities; these types of units were commonly called dry boxes as their original intent was to isolate radioactive materials. Throughout this report these terms should be considered equivalent.

A general approach for computation of a torso correction factor will be considered for a single glovebox using a radiation transport modeling software called ATTILA. Geometry is the variable of concern.

2.0 Special Exposure Considerations

Geometry deserves special consideration when conducting dose reconstructions for glovebox workers. This factor could result in an underestimation of the reconstructed dosimeter and missed dose to organs located in the lower torso region of the body (stomach, liver, bladder, prostate, ovaries, testes, etc…) The degree of underestimation is dependent the distance between the radiological source (exposure geometry), the materials used to construct the glovebox (attenuation or shielding), and the relative duration (time) that an energy employee conducted work in the glovebox. In general, very little is known about the duration of the exposure which is typically dependent upon the specific duties of the energy employee.

2.1 Exposure Geometry

Exposure geometry is a special consideration in dose reconstruction of energy employees who primarily worked in gloveboxes. An underestimation of the dose could occur if the energy employee wore his/her dosimeter on the lapel and not the center area of the chest or on the waist. This underestimation could result due to the difference in relative distance between the external radiation source, the organ of interest, and the dosimeter. Only organs in the lower torso are affected, since design of the glovebox places these organs closer to the radiological source than the dosimeter. The dose to lung is considered to have been reasonably approximated by the dosimeter at least to within the dosimeter uncertainty and the dose to the face and head would have been slightly lower than the dose measured by the dosimeter worn on the lapel.

2.2 Glovebox design

Low energy photons have a relatively low penetrating power and are easily attenuated. As a result, the design of the glovebox is an important consideration in accurately estimating the low energy photon dose. A review of the literature indicates that the design of gloveboxes varied widely.[1, 2] In some instances almost fully metal gloveboxes were used with only a small area for viewing (Figure 1), other gloveboxes had relatively large viewing areas (Figure 2-4), and others had a combination of multiple viewing areas with, in some designs, an opening that coincides with the center of the lower torso (Figure 5).

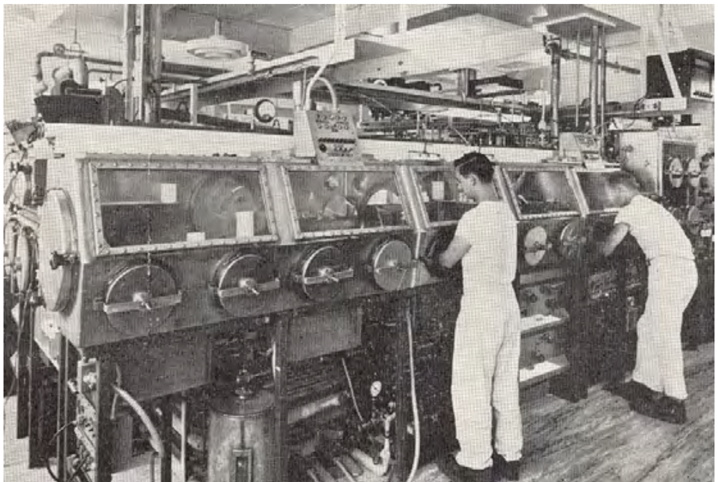

Figure 1 Plutonium gloveboxes at LANL (1)

Figure 2 Plutonium gloveboxes at Chalk River (1)

Figure 3 Plutonium gloveboxes at Hanford (2)

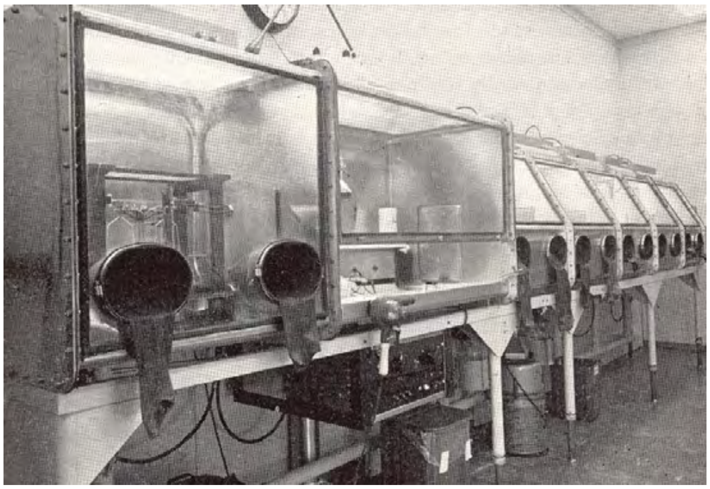

Figure 4 Plutonium gloveboxes at LANL's CMR facility (1)

Figure 5 Other plutonium gloveboxes at Hanford. Note the viewing area in direct line with the lower torso in the center between the gloves. (2)

Since the actual glovebox design is not known for each dose reconstruction scenario, a claimant favorable approach is used by assuming the glovebox had a large viewing face. This is considered a reasonable but necessary claimant favorable assumption, since identifying the actual glovebox design at each facility (DOE site, building, room, etc.) would be time consuming. In addition, during the course of an energy employee's employment, it is likely that they conducted work in many different types of gloveboxes, thus a time dependent work location correction factor for each glovebox design would be necessary to account for such differences. The effect of this assumption is to overestimate the dose to the lower organs rather than an underestimate.

While the face (viewing area) of a glovebox was typically constructed using a clear polymer type material such as Lucite[3], the sides and bases of gloveboxes are almost always constructed of sturdy materials such as wood, aluminum, and most commonly steel. These materials generally shield an individual worker from side exposure to low energy photons. As a result the low energy photon dose is virtually 100% from the anterior- posterior exposure geometry due to the radiological materials in the specific glovebox where the energy employee conducted his/her work. On the other hand, the intermediate and high energy photon dose would be a combination of the direct work in the glovebox as well as surrounding gloveboxes and process lines.

3.0 Methodology

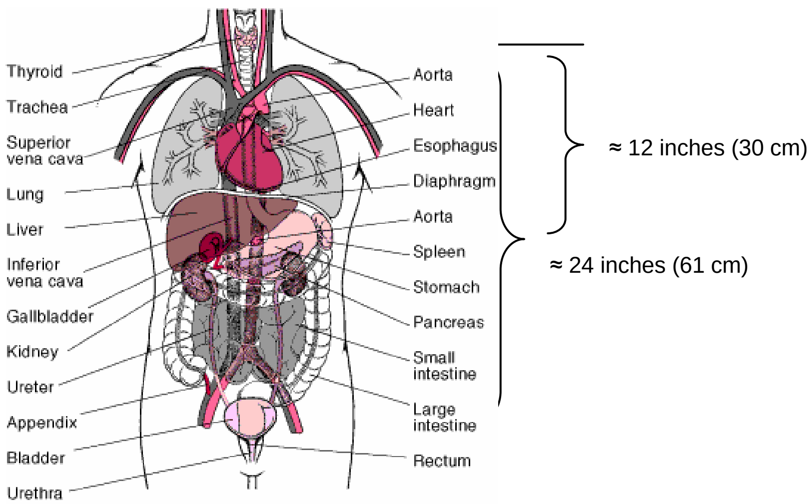

Figure 6 Diagram of Human Torso [4]

In the scenario used to develop a correction factor the radiation source was assumed to be directly in line with the specific organ of interest in the lower portion of the torso. To accurately estimate the underestimate of dose, the actual height of the glovebox and location of the source in relation to the energy employee's organ of interest and the distance to their lapel would be necessary (Figure 6). This analysis Used 24 inches as a reasonable claimant favorable assumption to simplify the calculation. In general, the correction factors for smaller stature workers would be less than those indicated in this technical information bulletin as the 24 inches is based on a moderately tall worker. In some instances, especially in the case of small stature workers, some of the organs could be below the bottom of the glovebox, thus low energy photons are virtually completely shielded (attenuated) and intermediate energy photons more attenuated than those measured on the dosimeter (Note the relative difference in worker stature in Figure 3).

As stated above, an average distance of 24 inches (61 cm) was assumed to be the distance between the lower torso and the lapel. The distance between the radiation source and the lower torso was assumed to vary from 6 inches to 18 inches. These distances were selected as the general range from which a worker could conduct most of their work in the glovebox. A source closer than 6 inches, while technically possible in some glovebox designs, is not very likely given the body location with respect to the glovebox. In some instances (Figure 2) a nearly straight down movement would be needed to position a source 6 inches from the lower torso. On the converse, 18 inches was selected as a reasonable upper distance. While some workers with longer arms might have been able to reach the back of the glovebox, a comfortable working distance for most workers would be between 10-14 inches between the source and the lower torso with a central tendency estimated at approximately 12 inches. This is used as the source distance.

At source distances greater than 48 inches, the relative difference between the dose to the lower torso and the lapel is less than 25% (factor 1.25) which is typically within the uncertainty of the dosimeter measurement. Thus the intermediate and high energy photon dose to the lower torso is approximately equal to the dose measured by the dosimeter on the lapel.

A model to determine the best-estimate correction factor for lower torso exposure to a glovebox worker was developed using modeling software called ATTILA. It is a multi-group deterministic radiation transport environment that can directly use Computer Aided Design (CAD) data and model complex geometry efficiently and accurately to solve large 3-D problems. Attila can solve neutron and photon transport equations and accounts for the same transport effects as Monte Carlo but is faster. Attila directly solves the differential form of the Boltzmann transport equation. A mesh is generated consisting of discrete points in space in the entire domain of the model. The transport equation is then solved for flux as a function of angle, energy and particle type, at every mesh point. Interpolation between mesh points is also performed.

The Attilla model's geometry and flux contours can be seen in Figure 7. The makeup of the glovebox is a stainless steel top, bottom and sides with a Lucite front face. This was deemed a more conservative, i.e. claimant favorable, design compared to boxes with partial stainless steel front faces. The human figure also provides for more of the lower torso to be exposed above the table top, again to be conservative.

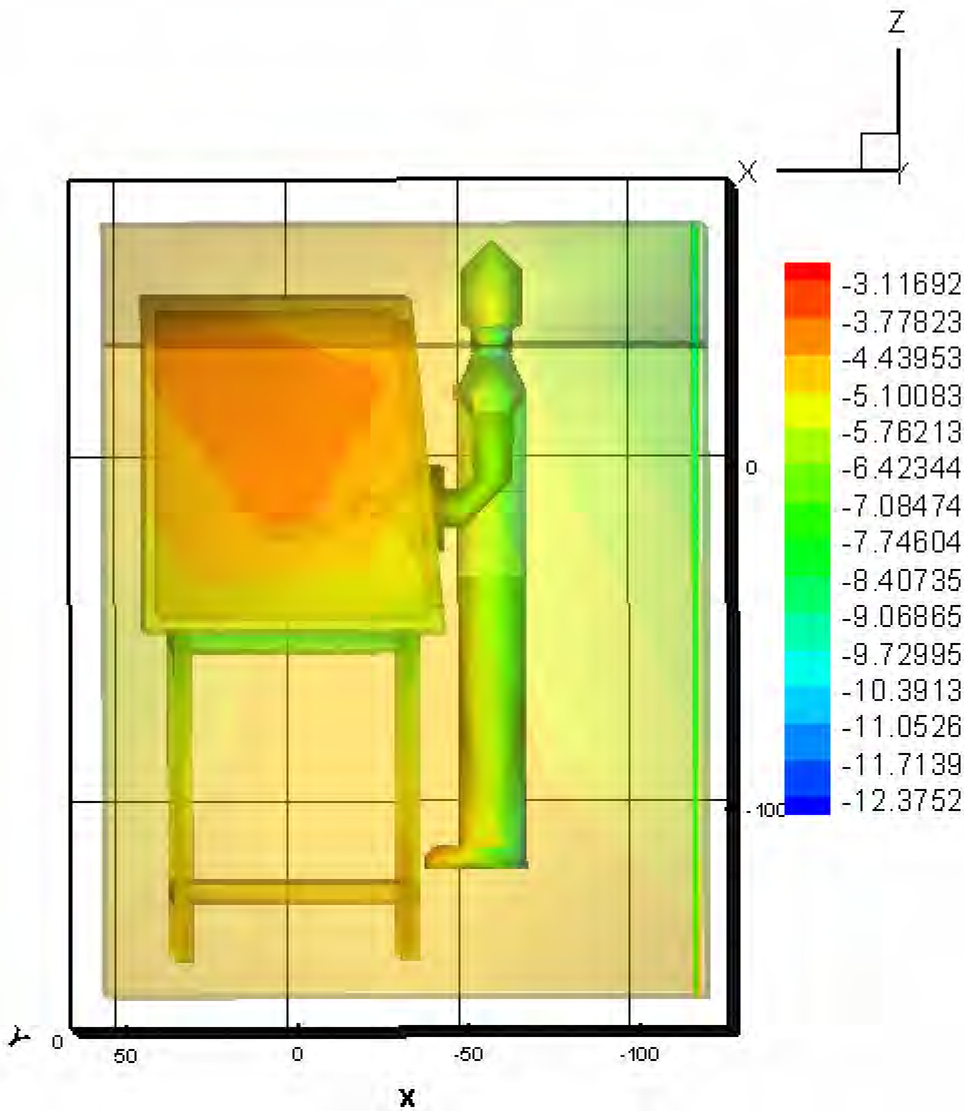

Figure 7 ATTILA model geometry and flux contours

3.1 Data analysis

ATTILA calculates photon flux at all mesh points in the domain of the problem. In order to avoid selection bias from a single-point calculation, data was extracted at 30 points each in the regions A and B on a plane perpendicular to the x-axis corresponding to the surface of the body (Figure 8). Flux distributions for each region were then determined by CRYSTAL BALL software. The flux data from region A and B follow a lognormal distribution. The regions A and B correspond to upper torso and lower torso respectively.

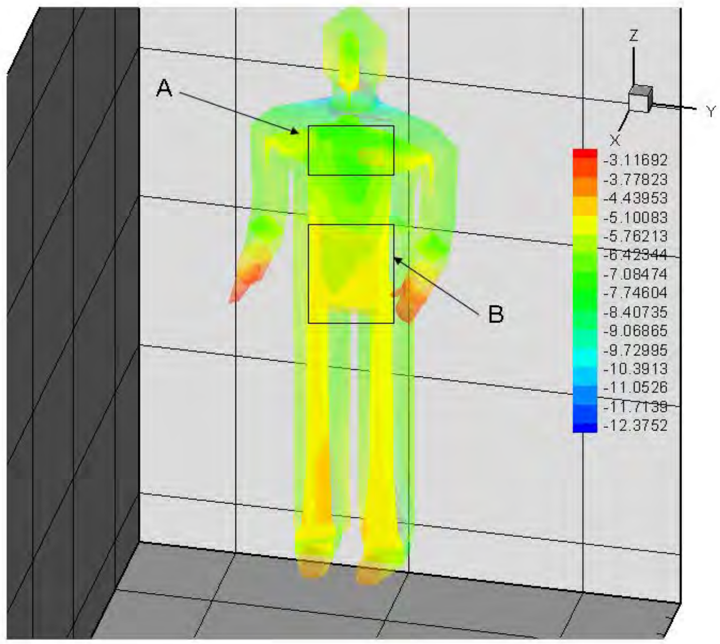

Figure 8 Data point selection regions. Various colors signify relative magnitude of flux across a selected plane on the x-axis.

Ratios between flux distributions in regions B and A formed another set of data for analysis by CRYSTAL BALL software.

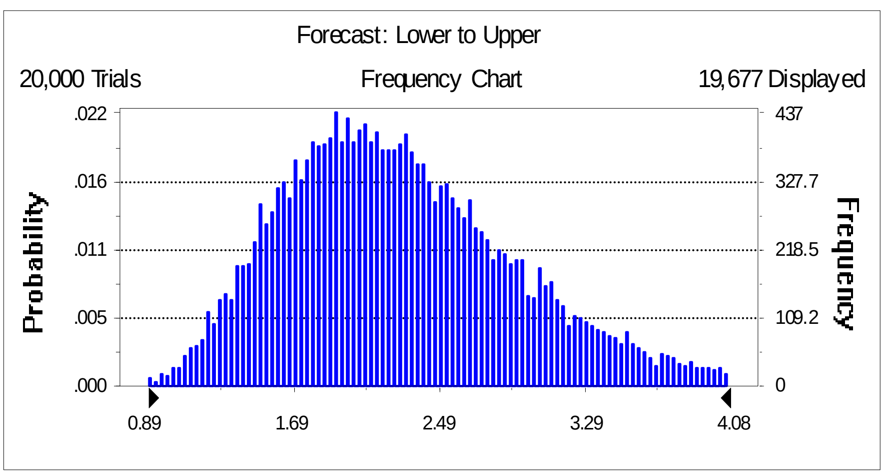

Figure 9 Distribution of lower torso to upper torso ratios

3.2 Results

An effort has been made to include the uncertainty of the dosimeter in the glovebox correction factor. There are two situations, one where the combination of dosimeter reading and organ DCF is a constant and the other where that value is a normal distribution with+/-30% standard deviation.

3.2.1 Geometric mean and standard deviation when dosimeter uncertainty constant

The resulting distribution of ratios from ATTILA was determined to be lognormal (Figure 9) with a geometric mean of 2.19 and a geometric standard deviation of 1.34. This mean and standard deviation will be applied to the dosimeter reading for deep dose when dosimeter correction factor is considered constant, i.e. equal to 1.3.

3.2.2 Geometric Mean and standard deviation when dosimeter uncertainty is a distribution

The resultant geometric mean and standard deviation for the distribution produced (Figure 9a) by CRYSTAL BALL when the lower-to-upper-torso distribution in Figure 9 is combined to a truncated normal dosimeter uncertainty distribution (only positive values are considered) is 2.3 and 1.13 respectively. This produces a glovebox correction factor that includes a dosimeter distribution uncertainty and is used when the dosimeter uncertainty of +/-30% needs to be considered.

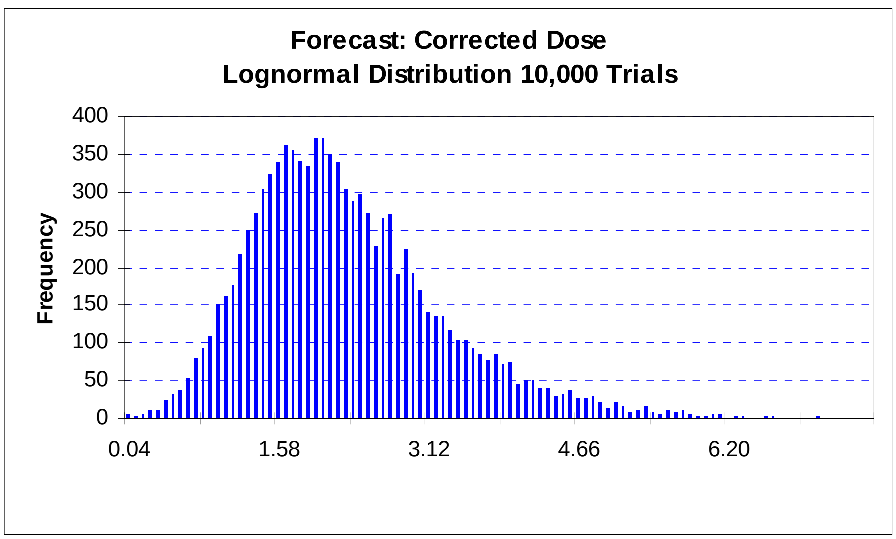

Figure 9a Combined distribution of lower-to-upper-torso ratio and dosimeter uncertainty

3.3 Reasonable Claimant Favorable Assumptions

Listed below are several claimant favorable assumptions used in the development of this methodology that could result in an overestimate of the actual dose.

- Claimant favorable glovebox design
- Direct line of sight to lower torso with Lucite as shielding
- Distance from lower torso to lapel based on tall workers

Obtaining data for precise evaluation of these parameters requires extensive time and research for each nuclear facility and in some instances the information cannot be obtained (e.g. facility has undergone D&D or other significant modification over time).

4.0 Applicability to Neutron Doses

The high energy photon correction factors described above may also be appropriate to measured neutron dose and potentially to some applications using neutron to photon (n-p) ratios. An evaluation of the applicability to neutron dose requires a site specific evaluation.

When a neutron to photon ratio method is used to estimate the neutron dose, it is important to know the general location of the photon and the neutron dosimeter. In the case of the Savannah River neutron to photon (n-p) ratios, the ratio was developed from joint measurement data of the TLD typically worn on the lapel and the neutron dosimeter (belly button dosimeter) worn around the waist. In this instance, the correction factor should not be applied since the measured neutron dose is a good representation of the dose to the lower torso. In later years, however, when the dosimeter combined photon and neutron TLD elements, a correction factor would need to be applied.

However at other facilities, if the NTA film dosimeter was worn on the lapel and a ratio was determined based on a photon dosimeter also worn on the lapel. Then the correction factor should be applied. The most efficient method for doing so would be to apply the correction factor to the photon dose before applying the neutron to photon ratio.

5.0 Summary

This Technical Information Bulletin provides guidance for dose reconstruction to organs located in the lower torso. The correction factors for best-estimate of dose provided in Table 1 respectively are for photons emanating from gloveboxes and measured using a dosimeter worn on the lapel. The factors should be applied for all photon energies and doses recorded either as the shielded element of the dosimeter or as the deep dose. The choice of factor will depend on whether the 30% dosimeter uncertainty is to be folded in or not.

Table 1 Lower torso **best-estimate** dose and/or exposure rate correction factors for glovebox work

Dosimeter uncertainty constant	**Distribution**	Geometric Mean		
Yes	Lognormal	2.19	1.34	
No	Lognormal	2.3	1.13	

6.0 Appendix – Verification of ATTILA model using wrist and lapel monitoring data from the Rocky Flats Plant

Wrist and whole body exposure data from the Rocky Flats Plant (RFP) were collected and used as a means to validate the use of ATTILA in modeling flux distributions. The ratio of wrist to whole body exposure was determined and then compared to a calculated value based on modeling. Exposure data from approximately 960 claims submitted to the EEOICPA program were analyzed. The claims include glovebox and non glovebox workers. The data were separated into two distinct periods at RFP: 1953-1969 and 1977-2001. In order to calculate a ratio of wrist dose to whole-body gamma dose at RFP, the neutron dose component must be subtracted from the reported penetrating dose quantity. The ability to do this is dictated by the availability of independent neutron dose data. For the period 1953-1969 this data was available from the Neutron Dose Reconstruction Project (NDRP). The analysis of this period was restricted to employees who had their dose reconstructed under the NDRP study and who are also EEOICPA claimants. For the years 1977-2001, the neutron data is separately reported in the records provided by DOE. The analysis of this period was not limited to those employees who had their dose reconstructed under the NDRP study. Additional analysis assumptions are shown below:

- Annual, quarter, and cycle data were compared – the maximum value was used
- Dose data from 1970 was excluded due to issues discussed in NDRP report

- Analysis performed excluding deep dose < 30 mrem and then < 100 mrem to determine potential variability due to badge doses near LOD
- Excluded extremity values <= 0

For completeness, an analysis was also done on the NDRP data for the years 1971-1997.

In all cases, the resulting analysis of wrist to whole-body ratios fit lognormal distributions. The results are tabulated below in Table 2. For comparison, the NDRP protocol reported a wrist to whole-body ratio of 2.5 based on1957 data.

Table 2a Wrist to badge ratio geometric means and standard deviations for Rocky Flats workers

Population	GM	GSD
NDRP (1953-1969) [Excluding < 30 mrem]	2.44	2.68
NDRP (1953-1969) [Excluding < 100 mrem]	2.42	2.54
All (1977 – 2001) [Excluding < 30 mrem]	2.72	2.18
All (1977 – 2001) [Excluding <100 mrem]	3.08	2.14

Table 2b

Population	GM	GSD
NDRP (1971-1997) [Excluding < 30 mrem]	2.24	2.28
NDRP (1971-1997) [Excluding < 100 mrem]	2.37	2.77

From ATTILA, flux distributions in regions A and C were combined to form a ratio between wrist and upper torso (Figure 10). This formed the basis of a data set to be analyzed by CRYSTAL BALL software. The wrist-to-upper-torso ratio distribution was lognormal with geometric mean of 2.64 and a geometric standard deviation of 3.13. (Figure11).

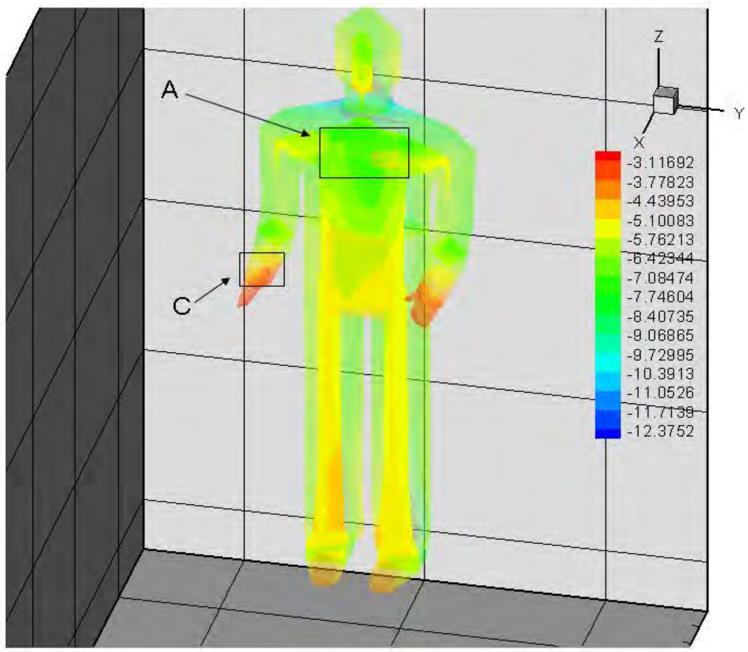

Figure 10 Data point selection regions. Various colors signify relative magnitude of flux across a selected plane on the x-axis.

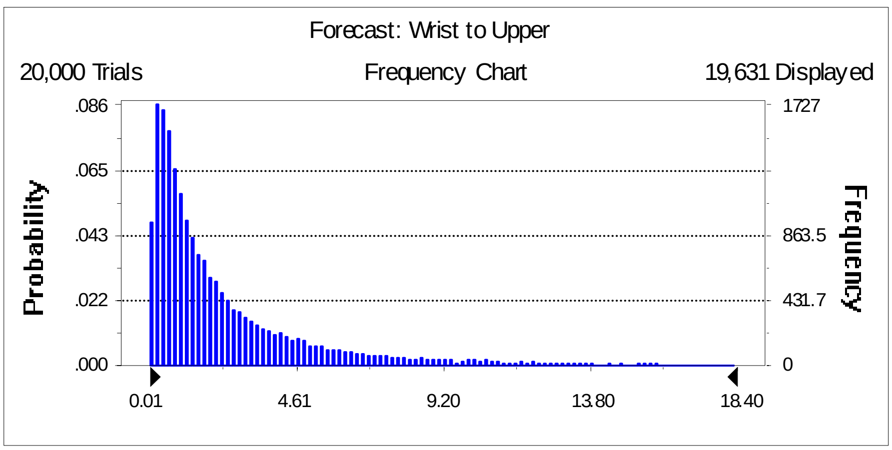

Figure 11 Distribution of wrist to upper torso ratios

This is in agreement with the RFP wrist-to-body-ratio geometric means and standard deviations in Table 2. Based on this analysis, it can be concluded that the ATTILA software is capable of producing reasonable and realistic results.

8.0 References

1. A. S. Coffinberry and W. N. Miner, The Metal Plutonium, The University of Chicago Press, Chicago, Illinois, 1961.

2. Office of Environmental Management, (1997) U.S. Department of Energy. Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences, DOE/EM-0319, U.S. Department of Energy, Washington D.C.

3. Watson, E. C. (1959) A Film Technique for Measuring the Exposure Dose from Plutonium, *Health Physics*, Vol. 2 pp. 207.

4. Merck (2004), The Merck Manual – Second Home edition, illustration obtained at the following website. http://www.merck.com/mrkshared/mmanual_home2/fg/fg001_1.jsp

5 Grove Engineering (2002), Microshield Program version 5 User Manual, Rockville Maryland.

6. Decisioneering Inc. (2000), Crystal Ball 2000 User Manual, Denver Colorado.

7. 42 CFR 82, *Methods for Radiation Dose Reconstruction Under the Energy Employee Occupational Illness Compensation Program Act of 2000*; Final Rule, Federal Register/Vol.67, No. 85/Thursday, May 2, 2002, p 22314.

8. NIOSH, (2002) External Dose Reconstruction Implementation Guideline, Rev 1, OCAS-IG-001, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio.

9. McGhee and Wareing (2004) Attila™ Version 4: User's Manual, Radion Technologies Los Alamos, NM