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REVISION HISTORY

Revision	Date	Purpose of the Revision
01	7/17/2007	Revision to accommodate additional operating systems.

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1. INTRODUCTION

1.1 Purpose

The purpose of the EXDOC_LA code is to calculate the expected dose, which is conditional on a disruptive event happening.

This document specifies a software design based on an explicitly articulated set of requirements. More specifically, it addresses the following aspects of the design:

- Operating Environment–In which the software will be used.
- Major Components–As they relate to the requirements.
- Technical Description–In terms of theoretical basis, mathematical model, control flow, data flow, control logic, and data structure.
- Input Range–In terms of allowable or defined range of values.
- Output Range–In terms of allowable or defined range of values.
- Mitigation Measures–To alleviate the consequences of potential problems.
- Test Plan–For validating the software.
- Software Problem Reports–None for this version.

1.2 Software Identification

This document contains the design of the software identified on the title page (EXDOC_LA Version 2.0).

The Software Configuration Control Request for EXDOC_LA Version 2.0 (Software Tracking Number: 11193-2.0-00) specifies the plan used to produce this document.

The Requirements Document for: EXDOC_LA Version 2.0 [Document ID: 11193-RD-2.0-01] specifies the requirements that the design implements.

1.3 Definitions

Acronyms used in this document are listed below.

CCDF	complementary cumulative distribution function
CDF	cumulative distribution function
CDSP	co-disposed spent
DLLs	Dynamic Link Library(ies)
EXE	executable
FD	fault displacement
GMD	ground motion damage
GUI	Graphical User Interface
LHS	Latin Hypercube Sampling
PC	personal computer
PDF	Probability Distribution Function

RD	Requirements Document
TSPA	Total System Performance Assessment
TSPA-LA	TSPA for the License Application
WP	waste package

1.4 Traceability

The Requirements Traceability Matrix (Document ID: 11193-RTM-2.0-00) documents the relationship between the following:

- The design elements (as specified in Section 3) and requirements (as specified in the RD).
- The test cases (as specified in Section 7.2) and design elements.
- The test cases (as specified in Section 7.2) and requirements (as specified in the RD).

2. OPERATING ENVIRONMENT

The program runs on personal computers (PCs) and servers using the Microsoft 32-bit Windows 2000, Windows XP, and Windows Server 2003 operating systems, but should also run on the other Microsoft 32-bit platforms (Windows 2000, or higher). At a minimum, a computer with a Pentium-class or higher CPU, at least 128 MB RAM, and 1GB of disk space is required.

3. DESIGN COMPONENTS

Identifiers accompanying each of the design components, such as (AR-01), refer to requirements as specified in the RD.

3.1 Design Component 1 (DC-01)–WINDOWS 32-BIT Operating System

The minimal hardware configuration to run EXDOC_LA Version 2.0 is a computer equipped with a Microsoft 32-bit Windows 2000, or higher, operating system, including Windows Server 2003, and Windows XP. (DR-01, AR-01)

3.2 Design Component 2 (DC-02)–Reads GoldSim Output Files

EXDOC_LA is developed as a standalone executable (EXE) with accompanying Dynamic Link Libraries (DLLs). Data generated by a qualified version of the GoldSim [DIRS 169844] software is used as input to this program. (DR-02, FR-04, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06)

In order to perform testing of the EXDOC_LA, data produced from any qualified version of the GoldSim software [DIRS 169844]) (i.e., V. 8.02.500 or greater) is required. The GoldSim user's guide (GoldSim Technology Group 2003 [DIRS 166226]) should be consulted for the specific output requirements. The GoldSim [DIRS 169844] data extraction is described in Section 5.

3.3 Design Component 3 (DC-03)–Self-Contained EXE and DLLs

The EXDOC_LA program will be self-contained. All necessary programs and libraries will be linked with the EXE and associated DLLs. (DR-01, AR-02)

3.4 Design Component 4 (DC-04)–Statistical Calculations

The Delphi code and FORTRAN libraries will implement the calculations as described in Section 4.1 and as shown in the flow diagram in Appendix A. (FR-01, FR-02, FR-03, FR-04, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, and OR-07)

3.5 Design Component 5 (DC-05)–Seismic Ground Motion Damage for Peak Dose Calculations

The seismic ground motion damage (GMD) for peak dose calculation will be implemented in the EXDOC_LA_MC subroutine. (FR_MC-01, FR_MC-02, FR_MC-03, FR_MC-04, FR_MC-05.a, FR_MC-05.b, FR_MC-05.c, and FR_MC-05.d).

3.6 Design Component 6 (DC-06)–Nominal Early Failure Modeling Case Calculations

The Nominal early failure modeling case calculations will be implemented in the EXDOC_LA_CV subroutine. (FR_CV-01, FR_CV-02, FR_CV-03, FR_CV-04, FR_CV-05.a, FR_CV-05.b, FR_CV-05.c, FR_CV-05.d, and FR_CV-05.e, IR-07, IR-08, IR-09).

3.7 Design Component 7 (DC-07)–Igneous Intrusive Calculations

The igneous intrusive modeling case calculations will be implemented in the EXDOC_LA subroutine. (FR-01, FR-02, FR-03, FR-04, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, and FR-06.f).

3.8 Design Component 8 (DC-08)–Igneous Eruptive Calculations

The igneous eruptive modeling case calculations will be implemented in the EXDOC_LA_MCT subroutine. (FR_MCT-01, FR_MCT-02, FR_MCT-03, FR_MCT-04, FR_MCT-05.a, FR_MCT-05.b, FR_MCT-05.c and FR_MCT-05.d).

3.9 Design Component 9 (DC-09)–Seismic Fault Displacement Calculations

The seismic fault displacement modeling case calculations will be implemented in the EXDOC_LA_FD subroutine. (FR_FD-01, FR_FD-02, FR_FD-03, FR_FD-04, FR_FD-05.a, FR_FD-05.b, FR_FD-05.c, FR_FD-05.d, IR-04, IR-07, IR-08, IR-09 and IR-10).

3.10 Design Component 10 (DC-10)–Seismic GMD for 10,000 Year Period Calculations

The seismic GMD scenario for a 10,000 year period calculations will be implemented in the EXDOC_LA_SE subroutine. (FR_SE-01, FR_SE-02, FR_SE-03, FR_SE-04, FR_SE-05.a, FR_SE-05.b, FR_SE-05.c, FR_SE-05.d).

3.11 Design Component 11 (DC-11)–Input File Transformation

Some of the data created by GoldSim [DIRS 169844] will be grouped in a single file. The EXDOC_LA_TR subroutine will function to separate the information into input files appropriate for the other subroutines. (FR_TR-01, FR_TR-02.a, FR_TR-02.b, and OR-08).

4. TECHNICAL DESCRIPTION

4.1 Theoretical Basis

The EXDOC_LA program shall implement the calculations described below. The EXDOC_LA code calculates the expected dose over aleatory uncertainty and estimates statistics on expected dose over epistemic uncertainty for the scenarios considered in the total system performance assessment (TSPA) calculations. The EXDOC_LA also calculates complementary cumulative distribution function (CCDF) over aleatory uncertainty and statistics on CCDF over epistemic uncertainty for a selected timestep.

4.1.1 Methodology

The global idea is to separate aleatory and epistemic uncertainty (Section 4.1.2), as is commonly done in risk analysis.

The solution is integrated over the aleatory uncertainty (for a fixed value of the epistemic parameters) to calculate an expected value, which is conditional on one epistemic element.

This operation is repeated for each sample element to obtain a group of expected curves. Statistics (here, mean and percentiles) are calculated on these curves.

The treatment of aleatory uncertainty is done in an inner loop, while the epistemic uncertainty is taken into account in an outer loop.

Moreover, the code calculates the related CCDFs (and associated statistics) to present both variability and uncertainty (Section 4.1.2) in the same graph.

Several modeling cases include an aleatory variable that describes the magnitude or extent of damage caused by a disruptive event. Although the definition of these aleatory quantities differs between modeling cases, the methods for interpolating values for these variables, or for integrating over the uncertainty in these variables, are exactly the same for different modeling cases. To take advantage of these similarities, EXDOC uses a generic variable termed an amplitude which, when paired with a time of an event, describes the aleatory uncertainty in the disruptive event. Table 4.1 lists the modeling cases and identifies the amplitude variable considered in each modeling case.

Table 4.1. Modeling Cases and Amplitude Variables

Modeling Case	Amplitude Variable
Nominal	None–no disruptive events occur
Nominal Early Failure	None–each affected package is assumed to be 100% damaged
Igneous Intrusive	Fraction of waste packages (WPs) destroyed
Igneous Eruptive	None–each affected package is assumed to be 100% damaged
Seismic GMD–10K yr	Fraction of area damaged on a WP
Seismic GMD–1M yr	Fraction of area damaged on a WP
Seismic Fault Displacement	Fraction of area damaged on a WP

4.1.2 Aleatory and Epistemic Uncertainty

The major purpose of the code is to separately treat aleatory and epistemic uncertainty. It is thus important to remember the differences between these two kinds of uncertainties:

- Epistemic uncertainty (known also as state of knowledge, subjective, and reducible uncertainty) reflects the lack of knowledge about data that are supposed to have fixed values. This uncertainty can be generally reduced by more studies and experiments.

- Aleatory uncertainty (known also as variability, stochastic, and irreducible uncertainty) is used to represent the uncertain future behavior one can expect of the system under study. This kind of uncertainty is not reducible.

The classification of an uncertain parameter into one or the other of these categories may be sometimes difficult and is not the purpose of this document. To simplify, we can say that one considers a parameter as epistemic if further research will lead to a better estimate of this parameter and aleatory if its uncertainty is inherent.

It is of course possible to treat both kinds of uncertainty together in an overall set of sampled values. This technique can yield a good estimate of the average expected dose and is generally less expensive in term of calculation. However, if epistemic and aleatory uncertainties are mixed together, few insights can be obtained through sensitivity analyses. In the results of the uncertainty analysis, one cannot determine what part of the uncertainty arises from epistemic uncertainty in the inputs and, thus, can be reduced, and what part of the uncertainty arises from aleatory uncertainty and is inherent in the analysis.

By separating aleatory from epistemic, one can have a better understanding of the behavior of the system studied and a better estimate of confidence in the system. For example, as proposed in this code, by treating the aleatory in an inner loop, one can see the variability of the system when the epistemic values are fixed. One CCDF, presented at a given time, will be informative regarding the likelihood to have an event of such amplitude, which is conditional of one epistemic set of parameters.

Moreover, with integrating over the aleatory uncertainty, one obtains an expected dose, which is conditional of one epistemic set. By calculating all the expected doses for each different sampled element, one can see, with the spread of expected doses, what is the uncertainty of the system. This spread (purely epistemic) is what one could hope to reduce if the epistemic quantities where known.

Since only the epistemic uncertainty is taken into account, one can perform a sensitivity analysis and determine which parameters must be studied first in order to optimize any reduction in uncertainty.

The following sections describe the methods for calculating dose in each modeling case.

4.1.3 Nominal Modeling Case

The Nominal modeling case represents performance of the repository in the absence of any early failure of WPs or drip shields and without the occurrence of any disruptive events. There are no aleatory uncertain variables in the Nominal modeling case. Hence, GoldSim [DIRS 169844] calculates a dose history for each realization of the epistemic variables. EXDOC_LA does not calculate any statistics for the Nominal modeling case.

4.1.4 Nominal Early Failure Modeling Case

The Nominal early failure modeling cases represent performance of the repository where either WPs or drip shields fail early due to manufacturing or material defects or emplacement error. WP early failure and drip shield early failure are separate modeling cases; however, the method of calculation is similar. This modeling case assumes no occurrence of disruptive events. The method described below is implemented in the EXDOC_LA_CV subroutine library.

The early failure modeling case includes the following aleatory variables:

- Number of WPs or drip shields experiencing early failure
- Type of WP (co-disposed spent [CDSP] or commercial spent nuclear fuel)
- Location of WP or drip shield (bin number 1-5)
- Dripping or non-dripping conditions.

The time of early failure is fixed at 10 years after repository closure and is not an uncertain quantity.

This modeling case assumes that GoldSim [DIRS 169844] produces a set of dose histories for each realization of epistemic uncertainty and for each combination of the aleatory variables type of WP, location of WP or drip shield, and dripping/non-dripping conditions, for a total of 20 dose histories for each epistemic realization. GoldSim [DIRS 169844] calculations should be done assuming a single WP or single drip shield fails. EXDOC_LA_CV performs the Monte Carlo integration over all aleatory variables, including the number of WPs or drip shields, to compute an expected (over aleatory variables) dose history for each epistemic realization and CCDFs of dose at points in time. The expected dose for each epistemic realization and package type is estimated by multiplying the dose by the expected number of packages and probability that this kind of package will fail (based on number of packages of this type, bin fraction, and dripping fraction). The total expected dose is equal to the sum of the expected doses for each package type.

The CCDF is calculated using a Monte Carlo technique as described in Section 4.2. First, the number of packages is randomly selected. Then, the location, dripping conditions, and type of packages is randomly determined. The resulting dose is calculated by summing all combinations of location, dripping condition, and package type. The operation is repeated several times for each epistemic set in order to create a CCDF over aleatory uncertainty.

4.1.5 Igneous Intrusive Modeling Case

The Igneous Intrusive modeling case represents a scenario with an intrusion of lava in the repository, due to igneous underground event. No volcanic eruption is included in this scenario.

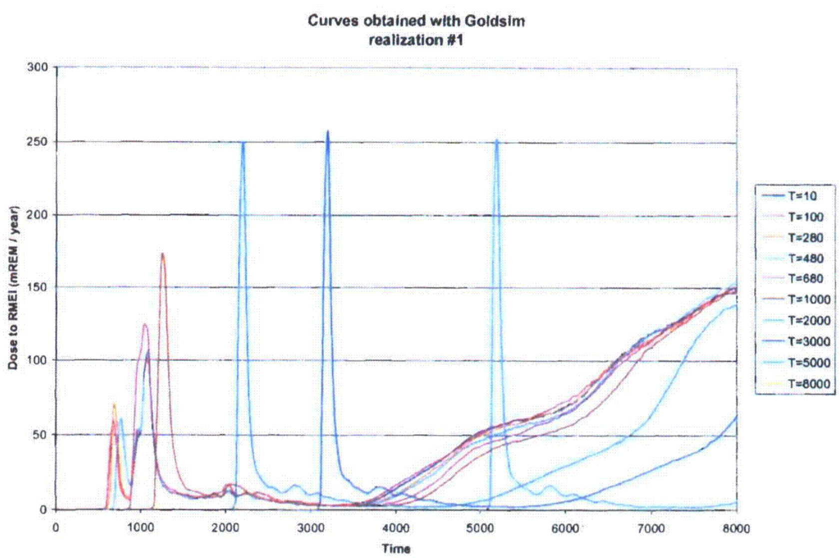
The calculation of expected dose and CCDF for the Igneous Intrusive modeling case is done with the EXDOC_LA subroutine library.

In this modeling case, two aleatory uncertainties are considered:

- The time of disruptive event (described by a Poisson law)
- The number of WPs destroyed by the igneous intrusion.

In the model currently used, it is assumed that the dose of the reasonably maximally exposed individual varies linearly with the number of WPs destroyed. This linearity assumption greatly reduces the number of calculations needed because calculations can be done with a fixed number of WPs and the results can be scaled. The linearity also simplifies the calculation of expected dose in the code because no integration is needed for this aleatory variable.

The time of a disruptive event is a little harder to take into account. Consider the following results:



Source: GoldSim [DIRS 169844]

Figure 1. Example of Doses for Different Times of Event, Conditional on a Given Set of Epistemic Parameters

One can see that the solutions are pretty well behaved for late event times. Making the calculation for a few fixed event times and linearly interpolating for other event times should be sufficient. Note that more event times are used early since the solution is not as well behaved as in late time.

A simple linear interpolation can be used to calculate the value at different times of events. This is considered as accurate enough for the purpose of integration (Figure 2). The calculation of the interpolated dose using simple linear interpolation would be obtained simply by applying Thales equality in a triangle:

```
Dose_interp = Dose_left +
              (t - t1)/(t2 - t1) ( Dose_right - Dose_left)
```

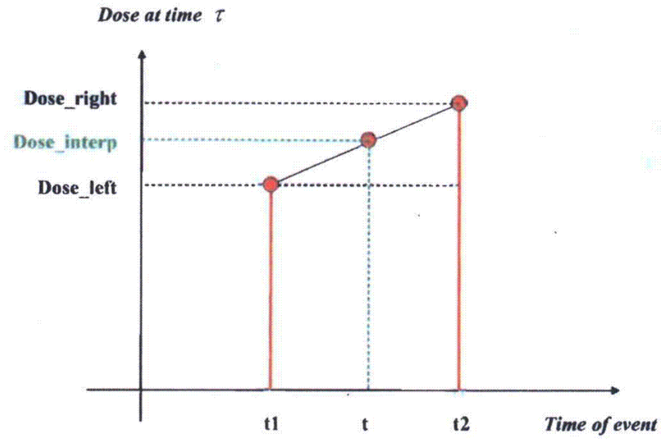


Figure 2. Simple Linear Interpolation Technique

However, this simple linear interpolation does not preserve the form of a curve over time. Consider, for example, these two pseudo-dose functions (Figure 3):

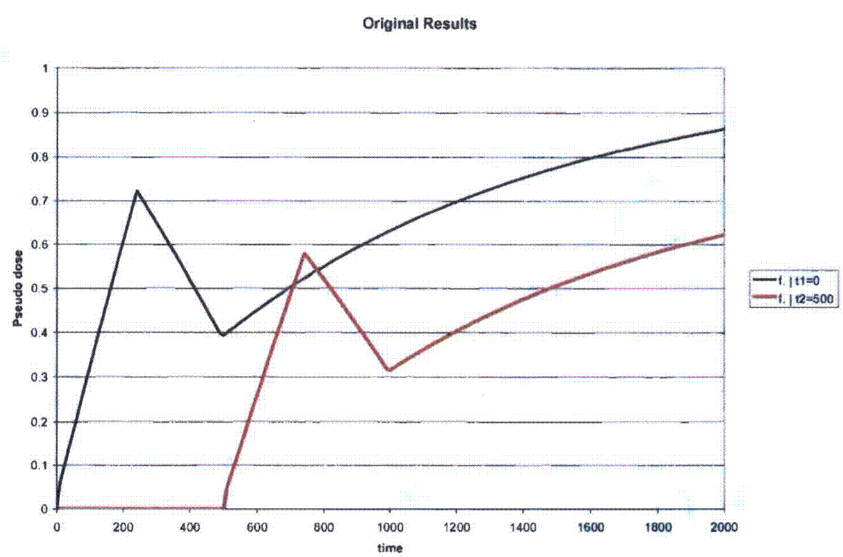


Figure 3. Pseudo-Dose Function for Two Different Times of Events (0 yr and 500 yr)

If a classical linear interpolation is made on the time of the event (in the example, every 100 yr, between 0 yr and 500 yr), then result in Figure 4 will be obtained. The curves do not reflect a reasonable estimate of the results of an event that occurs at 100, 200, 300, and 400 yr. The shape of the curve, dependent of the time of the event, must be preserved.

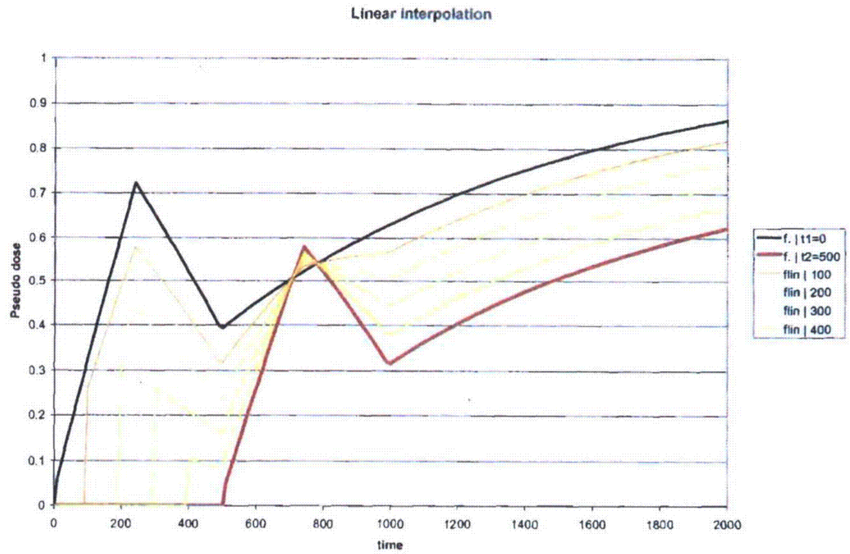


Figure 4. Classical Interpolation in the Pseudo-Dose Function

To preserve this shape, the interpolation performed between two curves is translated according to the time of event. For example, to interpolate the dose at a time Δt after an event that occurs at time t_I from the results of two events that occur at times t_L and t_R, with $t_L \leq t_I \leq t_R$, one will make the interpolation between the dose value at $t_L+\Delta t$ from the curve beginning at t_L, and the dose value at $t_R+\Delta t$ from the curve beginning at t_R, as shown in Figure 5. In other words, the interpolation is not based on the time considered but on the time elapsed after the event occurs. The result of such interpolation is presented in Source: GoldSim [DIRS 169844]

Figure 6.

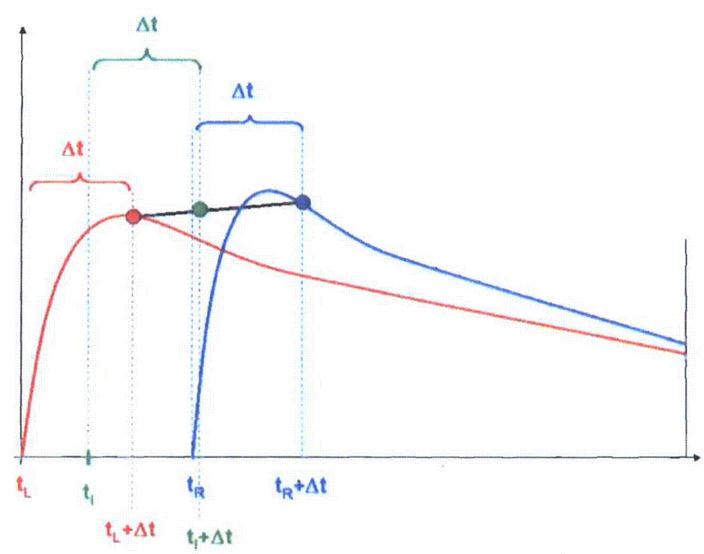
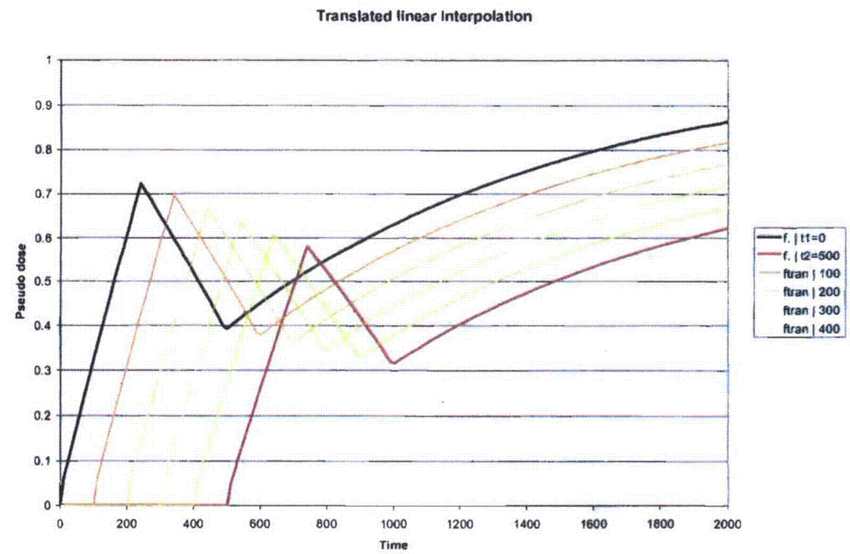


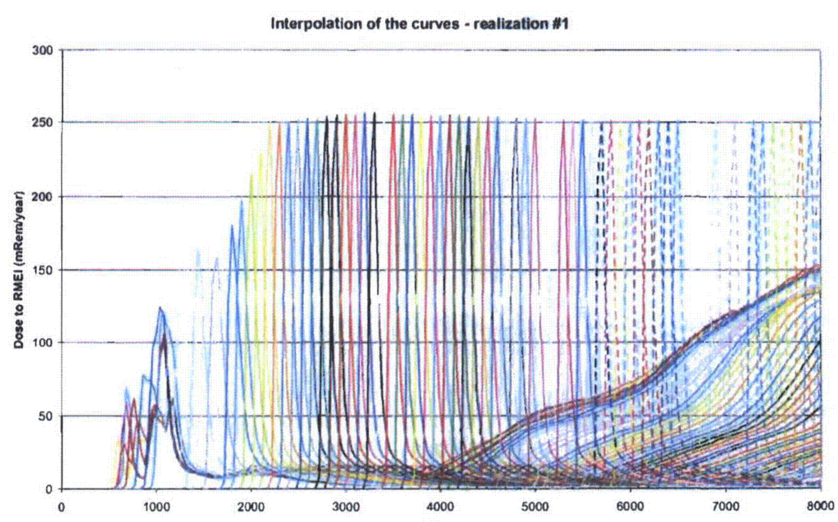
Figure 5. Illustration of Translated Interpolation



Source: GoldSim [DIRS 169844]

Figure 6. Translated Interpolation in the Pseudo-Dose Function

The result of this interpolation, applied to the dose presented in Figure 1, is presented below (Figure 7). One can see that this interpolation preserves the shape of the dose curves over time.



Note: This technique was used on the data presented in Figure 1.

Figure 7. Results of the New Interpolation Technique

The algorithm used is below. One can see that it is based on a simple linear interpolation. The only change is a shift to the left (respectively right) for the earlier (respectively later) time of event used for the interpolation.

```
tL = time of event used as a reference for the interpolation (left)
tR = time of event used as a reference for the interpolation (right)
t  = time of event for which the dose must be interpolated
τ  = time of the study (Tmin< τ < Tmax)
Dose(τ|tL) = dose calculated for a time of event tL (known)
Dose(τ|tR) = dose calculated for a time of event tR (known)

For τ = t to Tmax+t-t2

    Dose_left = Dose(τ-t+tL|tL)   (translation of data to the left)
    Dose_right= Dose(τ-t+tR|tR)   (translation of data to the right)


    Dose(τ|t) = Dose_left + (t - tL)/(tR - tL)
    (Dose_right - Dose_left) (interpolation)

End for
```

Note that τ-t = Δt (Figure 5).

When the right endpoint of the interpolation, $t_R+\Delta t$, falls past the end of the data, EXDOC_LA assumes that $t_R+\Delta t = t_L+\Delta t$.

The Igneous Intrusion modeling case assumes that GoldSim [DIRS 169844] produces a set of dose histories $D_{II}(\tau|t_k, NWPD, e_j)$ for each realization of epistemic uncertainty e_j and for each set of times of intrusion $\{t_k\}$ and with the assumption that all packages ($NWPD$) are destroyed by the intrusion. The expected dose for each epistemic realization, $\overline{D}_{II}(\tau|e_j)$, is estimated by:

$$\begin{aligned}\overline{D}_{II}(\tau|e_j) &= \int_{nMIN}^{nMAX}\int_{tMIN}^{\tau} D_{II}(\tau|t, nWPD, e_j)\lambda_{I|e_j}\, dt\, d_n(nWPD)\, dn \\ &\cong \lambda_{I|e_j}\frac{E(nWPD)}{NWPD}\int_{tMIN}^{\tau} D_{II}(\tau|t, NWPD, e_j)\, dt \qquad \text{(Equation 1)}\end{aligned}$$

where $nWPD$ is the number of packages destroyed by the intrusion, $NWPD$ is the number of packages in the repository, $d_n(nWPD)$ is the density function for the number of WPs destroyed by the intrusion, $\lambda_{I|e_j}$ is the frequency of occurrence of igneous events for the j^{th} epistemic realization, and the integration of $D_{II}(\tau|t, NWPD, e_j)$ over t is carried out numerically using the interpolation technique described above.

The CCDF for dose at a specific point in time can be computed using the Monte Carlo method outlined in Section 4.2.

4.1.6 Igneous Eruptive modeling case

The Igneous Eruptive modeling case represents the dose that occurs as a consequence of an eruptive conduit intersecting waste and ejecting waste into the atmosphere. No other igneous or seismic consequences are included in this scenario. The calculation of Expected Dose and CCDF for Igneous Eruptive modeling case is done with the EXDOC_LA_MCT subroutine library.

The Igneous Eruptive modeling case considers the following aleatory variables:

- Time of eruptive event
- Number of WPs ejected
- Magma partitioning factor (fraction of waste entrained that is ejected into the atmosphere)
- Eruptive power
- Eruptive duration
- Wind direction
- Wind speed.

Other aleatory quantities (e.g., eruptive height) used in the eruptive modeling case are calculated as functions of the aleatory variables listed above.

The aleatory variables are separated into two sets:

A_1, consisting of time of eruptive event, number of WPs ejected, and magma partitioning factor; and A_2, consisting of eruptive power, eruptive duration, wind direction, and wind speed. GoldSim [DIRS 169844] calculations are performed for each epistemic realization e_j, each realization in the set A_2, and each time in a set of event times $\{t_k\}$, with the number of WPs ejected and the magma partitioning factor both set to one. EXDOC_LA_MCT calculates the expected dose for Igneous Eruptive modeling case by interpolating in time as in the Igneous Intrusion modeling case (Section 4.1.5) and using a Monte Carlo method to integrate over the sets A_1 and A_2. Specifically, the expected dose for each epistemic realization, $\overline{D}_{VE}(\tau|e_j)$, is estimated by:

$$\overline{D}_{VE}(\tau|e_j) = \int_{A_1}\int_{A_2}\int_{tMIN}^{\tau} D_{VE}(\tau|a_1, a_2, e_j)\lambda_{I|e_j} d_{A_1}(a_1) d_{A_2}(a_2) dt$$

$$\cong \lambda_{I|e_j} \int_{A_2}\int_{nMIN}^{nMAX}\int_{mMIN}^{mMAX}\int_{tMIN}^{\tau} D_{VE}(\tau|t, nWP, m, a_2, e_j)\lambda_{I|e_j} d_m(m) d_n(nWP) d_{A_2}(a_2) dt dn dm$$

$$\cong \lambda_{I|e_j} E(m) E(nWP) \frac{1}{nS_2} \sum_{a_{2,i}=1}^{nS_2} \int_{tMIN}^{\tau} D_{VE}(\tau|t, 1, 1, a_{2,i}, e_j) dt \qquad \text{(Equation 2)}$$

where *nWP* is the number of packages ejected, $d_n(nWP)$ is the density function for the number of WPs ejected, $\lambda_{I|e_j}$ is the frequency of occurrence of igneous events for the j[th] epistemic realization, *m* is the magma partitioning factor, $d_m(m)$ is the density function for the magma partitioning factor, $a_{2,i}$ is one of nS_2 realizations from the set A_2, and the integration of $D_{VE}\left(\tau \middle| t,1,1,a_{2,i},e_j\right)$ over t is carried out numerically using the interpolation described in Section 4.1.5 based on the GoldSim [DIRS 169844] calculations.

The CCDFs at a given time are estimated using a Monte Carlo method. First a time of event is selected randomly. Then an element of the set A_1 is selected randomly, as are values for the aleatory variables in A_2. The resulting dose is estimated from the GoldSim [DIRS 169844] results. The operation is repeated several times for each epistemic set in order to create a CCDF over aleatory uncertainty.

4.1.7 Seismic GMD Modeling Case for 10,000 Years

The Seismic GMD 10K modeling case represents the dose that results from a seismic ground motion event that damages the WPs and drip shields. The Seismic GMD modeling case for 10,000 years assumes that a single seismic event occurs during the time period and that no other disruptive events occur. The calculation of Expected Dose and CCDF for the Seismic GMD modeling case is done with the EXDOC_LA_SE subroutine.

The Seismic GMD 10K modeling case considers the following aleatory variables:

- The time of seismic event (described by a Poisson law)
- The peak ground velocity of the seismic event
- The fraction of surface area damaged on each type of WP due to the seismic event.

The Seismic GMD 10K modeling case assumes that GoldSim [DIRS 169844] produces a set of dose histories $D_{SE}\left(\tau \middle| t_k, A_i, e_j\right)$ for each realization of epistemic uncertainty e_j, each of a set of times of occurrence $\{t_k\}$, and each of a set of fraction of surface area damaged on a WP $\{A_i\}$.

The synergism between multiple events is accounted by using a different distribution of surface area damaged once the package has degraded interiors. This status is reached once there is one seismic event causing any damage to the package.

The expected dose at a given point in time τ, conditional on an epistemic realization, e_j, $E\left[D(\tau \mid e_j)\right]$, is given by

$$E\left[D(\tau \mid e_j)\right] = \int_0^{\tau} \{\lambda_1 \exp[-\lambda_1 t]\} \left[\int_{A\min}^{A\max} D(\tau \mid t, A, e_j) d_{A1}(A) dA\right] dt + \int_0^{\tau} \{\lambda_1 \exp[-\lambda_1 t]\} \left\{\int_t^{\tau} \left[\int_{A\min}^{A\max} D(\tau \mid t, A, e_j) d_{A2}(A) dA\right] \lambda_2 d\tilde{t}\right\} dt \qquad \text{(Equation 3)}$$

where

$D(\tau \vert t, A, e_j)$	=	dose at time τ resulting from an event at time t with fraction of damaged area A, conditional on a realization of epistemic uncertainty e_j
τ	=	current time
t	=	time of first event
$\tilde{t}$	=	time of subsequent events
A	=	fraction of surface area damaged
$d_{A1}(A)$	=	density function of the fraction of surface area damaged for first event
$d_{A2}(A)$	=	density function of the fraction of surface area damaged for subsequent events
λ_1	=	annual frequency of having a first seismic ground motion event damaging WPs
λ_2	=	annual frequency of having subsequent seismic ground motion events damaging WPs.

The first term on the right side of Equation 3 estimates the contribution of the first event on the dose to the reasonably maximally exposed individual. As this event is considered to have a different impact than subsequent events, it is conditioned on happening exactly once over the time period (multiplication by $\{\lambda_1 \exp[-\lambda_1 t]\}$ within the integral).

Subsequent events are conditioned on one event happening first (first integration over t with multiplication by $\{\lambda_1 \exp[-\lambda_1 t]\}$ and second integration over $\tilde{t}$ beginning after the first event, so at t and not 0). However, multiple subsequent events are considered (multiplication by λ_2 within the second integral).

The integrals over surface area damage for the first event and subsequent events are treated similarly only using a different density function.

$$\text{Let } \overline{D}_{Ak}(\tau \mid t, e_j) = \int_{A\min}^{A\max} D(\tau \mid t, A, e_j) d_{Ak}(A) dA \qquad \text{(Equation 4)}$$

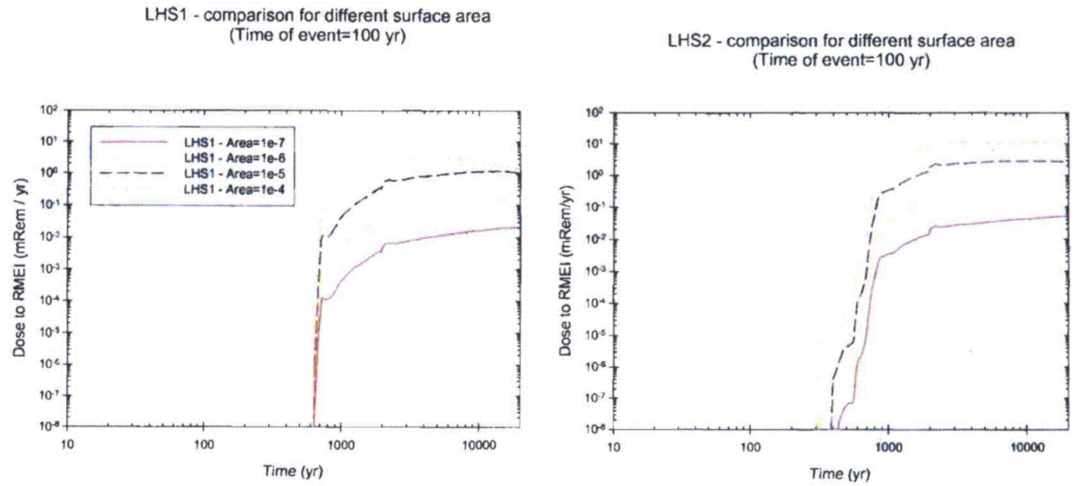
By evaluating $D(\tau \vert t, A, e_j)$ at a set of values $\{A_i\}$, we have the following approximations:

$$
\begin{aligned}
\overline{D}_{Ak}(\tau \mid t, e_j) &= \sum_{i=1}^{nA} \int_{A_{i-1}}^{A_i} D(\tau \mid t, A, e_j)\, d_{Ak}(A)dA \\
&\cong \sum_{i=1}^{nA} \int_{A_{i-1}}^{A_i} D(\tau \mid t, A_{i-1}, e_j) + \frac{A - A_{i-1}}{A_i - A_{i-1}} \left[D(\tau \mid t, A_i, e_j) - D(\tau \mid t, A_{i-1}, e_j) \right] d_{Ak}(A)dA \\
&\cong \sum_{i=1}^{nA} D(\tau \mid t, A_{i-1}, e_j) \int_{A_{i-1}}^{A_i} d_{Ak}(A)dA \\
&\quad + \sum_{i=1}^{nA} \frac{\left[D(\tau \mid t, A_i, e_j) - D(\tau \mid t, A_{i-1}, e_j) \right]}{A_i - A_{i-1}} \int_{A_{i-1}}^{A_i} (A - A_{i-1})\, d_{Ak}(A)dA \\
&\cong \sum_{i=1}^{nA} D(\tau \mid t, A_{i-1}, e_j)\, \boxed{prob_{Ak}(A_{i-1} \le A \le A_i)} \\
&\quad + \sum_{i=1}^{nA} \frac{\left[D(\tau \mid t, A_i, e_j) - D(\tau \mid t, A_{i-1}, e_j) \right]}{A_i - A_{i-1}} \left\{ \boxed{\int_{A_{i-1}}^{A_i} A\, d_{Ak}(A)dA} - A_{i-1}\, \boxed{prob_{Ak}(A_{i-1} \le A \le A_i)} \right\}
\end{aligned}
\qquad \text{(Equation 5)}
$$

The two terms, bordered in red, are independent of the dose calculation. Their only dependency is on the discretization of the fraction of area damaged and the probability law associated to the fraction of area damaged. Since both quantities are known at the beginning of the calculation, the two terms can be calculated once and used in each interpolation on the time of event and for each Latin Hypercube Sampling (LHS) realization (Helton & Davis 2002 [DIRS 163475]). This expedites the calculation of the expected dose.

This technique assumes a linear relationship between fraction of area damaged and resulting dose. The assumption is consistent with the advective and diffusive transport models in which area is a linear scalar in the equations for radionuclide concentration in the invert. The effect of this assumption on TSPA model results is discussed below.

Figure 8 illustrates the ratio between the dose that results from calculations assuming three different quantities of area damaged on a package: 1e-7, 1e-6, 1e-5, and 1e-4, for a single seismic event and a fixed set of epistemic quantities (in this figure, the area damaged is the actual area, not the fraction of surface area). As the damaged area increases, the resulting doses increases. Although the increase is sublinear rather than linear, the curves in Figure 8 show that when the epistemic parameters are fixed, the results for different levels of WP damage are similar, so linear interpolation should yield a good approximation for varying levels of WP damage.



Note: Time of event = 100 yr

Figure 8. Dose Behavior When Only Surface Area is Changing for 2 Realizations of the Sample

For a sublinear relation similar to those shown in Figure 8, a classical linear-interpolation technique (as described in Figure 2) is really efficient. In the region were the sublinearity is strong, the curves are closer to each other, and the linear interpolation gives a good estimate of the value interpolated.

The integration of $\overline{D}(\tau|t, e_j)$ over t is carried out numerically using the same interpolation technique described for the Igneous Intrusion modeling case in Section 4.1.5.

EXDOC_LA_SE uses a Monte Carlo technique to generate a CCDF of dose at each point in time for the Seismic GMD 10K modeling case.

The CCDF estimation is done using a Monte Carlo approach. For each epistemic sample element, an aleatory sample is created. First, it is determined if at least one event occurs. If this event occurs, a time of event is determined randomly. Then, the number of subsequent events is randomly determined for the remaining time (i.e., from the time to the first event until the time for which the CCDF is calculated). Doses from all individual events are summed to obtain an estimated dose at a given time. The repetition of this approach for each aleatory sample element leads to the estimation of a CCDF for a given epistemic sample element.

4.1.8 Seismic GMD Modeling Case for 1M Years

The Seismic GMD modeling case for 1 million years differs from the Seismic GMD case for 10K years by accounting for multiple seismic events that occur in the 1M year calculation period. No other disruptive events are included in this scenario. The calculation of expected dose and CCDF for the Seismic GMD modeling case for 1M years is implemented in the EXDOC_LA_MC subroutine library.

In the 1M year calculation, GoldSim [DIRS 169844] uses LHS to generate realizations of epistemic parameters $\{e_j\}$ and Monte Carlo sampling to generate realizations $\{a_i\}$ of aleatory variables. In this case, each realization $\{a_i\}$ of aleatory variables defines a possible sequence of ground motion events that could occur between repository closure and 1M years. GoldSim [DIRS 169844] generates a dose history $\{D_{i,j}\}$ for each epistemic realization $\{e_j\}$ and each realization $\{a_i\}$ of aleatory variables. EXDOC_LA_MC simply calculates expected dose and quantiles over aleatory uncertainty and sorts the data to represent the CCDF.

4.1.9 Seismic Fault Displacement

The Seismic Fault Displacement modeling case represents the dose that occurs as a consequence of a fault displacement seismic event that damages WPs and drip shields. Fault displacement events are assumed to occur independent of ground motion events. No other disruptive events are included in this scenario. The calculation of Expected Dose and CCDF for the Seismic Fault Displacement modeling case is done with the EXDOC_LA_FD subroutine library.

The Seismic Fault Displacement modeling case considers the following aleatory variables:

- Time of seismic event
- Number of WPs damaged of each WP type
- Fraction of WP surface area damaged for each WP type
- Location of damaged WPs (bin number 1-5)
- Dripping conditions at locations of damaged WPs (dripping/non-dripping).

This modeling case assumes that GoldSim [DIRS 169844] produces a set of dose histories for each realization of epistemic uncertainty and for the following values of the aleatory variables: 1 WP of each type (CDSP and transportation, aging, and disposal canister); fraction of area damaged {1/3, 2/3, 1}, same value for either WP type; package location (bin 1 through bin 5), and dripping or non-dripping conditions, for a total of 60 dose histories for each epistemic realization. The calculation of a mean dose history for each epistemic realization involves two steps. First, EXDOC_LA_FD uses a quadrature technique to numerically integrate over the time of the fault displacement event and the fraction of surface area damaged, for each combination of WP type (CDSP or transportation, aging, and disposal canister), location (bin 1 through bin 5), and dripping condition (dripping or non-dripping). The mean dose at each point in time is calculated by adding the quadrature results for a given package type, multiplying by the expected number of packages damaged of that type, and finally adding the dose resulting from each package type.

For each epistemic set, the CCDF at a given time is calculated using a Monte Carlo method to randomly select times of event, number of WPs damaged of each type (amplitude of event), fraction of damaged area, location, and dripping condition. The resulting dose is estimated. The operation is repeated to construct a CCDF over aleatory uncertainty.

4.1.10 Transformation of GoldSim Output File

Versions 1.0 and 1.1 of the program were supposing that GoldSim [DIRS 169844] was giving a different file for each aleatory set. At this time there were no looping capabilities that allowed creating a unique file in GoldSim [DIRS 169844]. Since then, a looping capability has been added so that it is possible to generate several runs with different aleatory value.

Instead of changing the code in consequence, it has been decided that a translator will be developed to split a big file where aleatory and epistemic uncertainty changes into several separate files, in which only epistemic uncertainty is changing. The reasons for this choice include the following:

- There is a structure in the way the data will be saved when more than one aleatory parameter is involved. This structure is likely to change with time.
- When the discretization method (over time of event or fraction of surface area damaged, for instance) is applied, we make the supposition that the results are smooth enough between two selected values so that a linear interpolation will efficiently cover the area between the two values. This is possible, when looking at the results, that more values have to be added to have a better discretization. In this case, having a way to renumber the runs and add new runs is valuable.
- It is possible to use a unique standard format for all DLLs. However, while it is possible to handle the standard format for consistency, EXDOC_LA_MC.DLL allows using GoldSim [DIRS 169844] results directly for faster calculations.

4.2 Mathematical Model

The mathematical models for portions of the EXDOC_LA code that have a degree of complexity are described below.

4.2.1 CCDF Calculation

Several methods may be used to calculate the CCDF for a given time.

Discretization method

If a CCDF calculation involves two aleatory variables, termed event time and amplitude, and the assumption that a single event has occurred, then the discretization method can be used to generate the CCDF. The event time is discretized uniformly. The amplitude can be discretized either uniformly, log-uniformly, or according to the quantiles of the amplitude distribution. This leads to a 2D discretized domain, as in Figure 9.

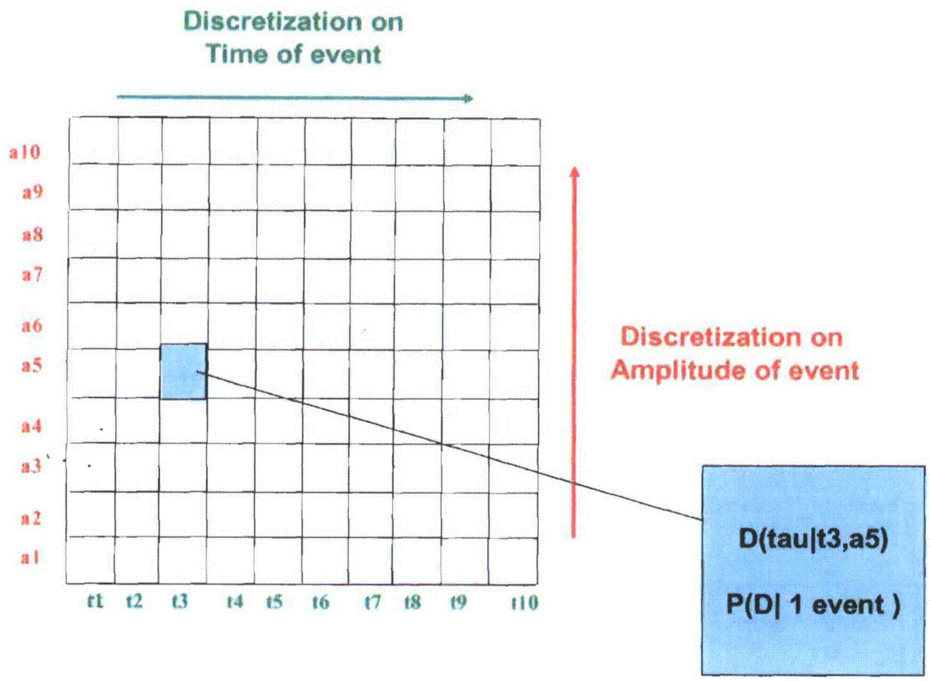


Figure 9. Discretization of Variability for the Dose at Time Tau.

Then, for each cell, the value of the dose is interpolated, as well as a probability of occurrence, which is conditional on exactly one event happening.

The dose values are then sorted (in increasing order). The probability of having a dose greater or equal to a given value D is obtained by starting with the probability of having at least one event ($= (1 - e^{-\lambda t})$), subtracting the probability calculated for each cell in which the dose is less than D, and finally multiplying by $(1 - e^{-\lambda t})$ (to normalize the CCDF for the assumption that a single event has occurred).

This method has the advantage to produce a mapping on the aleatory uncertainty, which can be represented in a 2D or 3D graph to have a better understanding of the variability (Figure 9).

However, this method has the drawback of considering only one event. The assumption of a single event is reasonable if the probability of having two or more events during the time interval considered is below the minimum probability of interest in the CCDF.

If the LOG_INFO variable is greater than 4, the accuracy of each sample (based on the value of lambda and on the time considered) is written in the log file for each sample.

Monte Carlo method

The Monte Carlo method consists in generating randomly a set of possible future (including multiple disruptive events) for a given set of epistemic parameters. The algorithm used is described below

1. First Step

The events (igneous or seismic) are modeled with a Poisson process. This means that probability of having k events of frequency λ for a period T is equal to:

$$P(nEV_i = k) = \frac{(\lambda T)^k}{k!} e^{-\lambda T} \qquad \text{(Equation 6)}$$

The probabilities, when k goes to infinity are summing to 1.

A simple way to determine randomly the number of events is to generate a random number between 0 and 1 and to match this probability to the corresponding number of events.

```
nEV(i)        =      0
p             =      rand()
pcomp         =      exp(-lambda x T)
multiplier    =      1
DO while (p>pcomp)
      nEV(i)        = nEV(i)+1
      multiplier    = multiplier * (lambda x T)
                      / nEV(i)
      pcomp         = pcomp + ( exp(-lambda x T)
                      * multiplier)
END DO
```

The probability of having 0 events is thus equal to $P(nEV_i = 0) = e^{-\lambda T}$.
The probability of having 1 or more events is equal to $P(nEV_i \geq 1) = 1 - e^{-\lambda T}$.

In our estimation, we do not need to calculate any dose due to zero events (since we know that the dose will be zero). The estimation will converge faster if we calculate the dose for 1 or more events (ignoring the no-event) and scaling the CCDF according to the probability of having 1 or more events (i.e., $\times 1 - e^{-\lambda T}$).

The algorithm can then be rewritten the following way:

```
nEV(i)        =      1
p             =      rand()x (1 - exp(-lambda x T))
multiplier    =      (lambda x T)  / nEV(i)
pcomp         =      exp(-lambda x T)* multiplier

DO WHILE (p>pcomp)
      nEV(i)        = nEV(i)+1
      multiplier    = multiplier * (lambda x T)
                      / nEV(i)
      pcomp         = pcomp + ( exp(-lambda x T)
                      * multiplier)
END DO
```

2. Estimation of Time of Each Event

Knowing the number of events occurring during T years, it is easy to determine the time of each events because they are uniformly distributed.

```
DO k=1, nEV(i)
      Tau(k,i) = RAND()*T
END DO
```

3. Estimation of Amplitude of Each Event

The term amplitude refers to the aleatory quantities that determine the extent or magnitude of each event, which are different depending on the modeling case considered. For the Igneous Intrusive modeling case, the amplitude is the number of WPs destroyed by the intrusion. For the Seismic Fault Displacement modeling case, the amplitude is the fraction of surface area damaged on a WP. The amplitude is sampled from its cumulative distribution function (CDF) by randomly generating a number between 0 and 1. This number is used as a quantile value in the distribution of amplitude. Once this value is known, the corresponding dose for this amplitude is either linearly extrapolated (igneous case) or linearly interpolated (seismic case).

```
DO k=1, nEV(i)
      QUANTILE(k,i) = RAND()*T
      AMPLITUDE(k,i) = linear_interpolation
                        (QUANTILE(k,i),distribution_amplitude)
END DO
```

4.2.2 Sorting method

Different methods for sorting an array of data have been developed. The most famous methods are the quick sort, heap sort, and shell sort methods.

The first two are the fastest and give good solutions in n. log(n) calculations (where n represents the number of data to sort). The third one is the easiest to implement and gives the solution in n^1. 25 calculations. The difference in convergence between these methods can be seen in Figure 10.

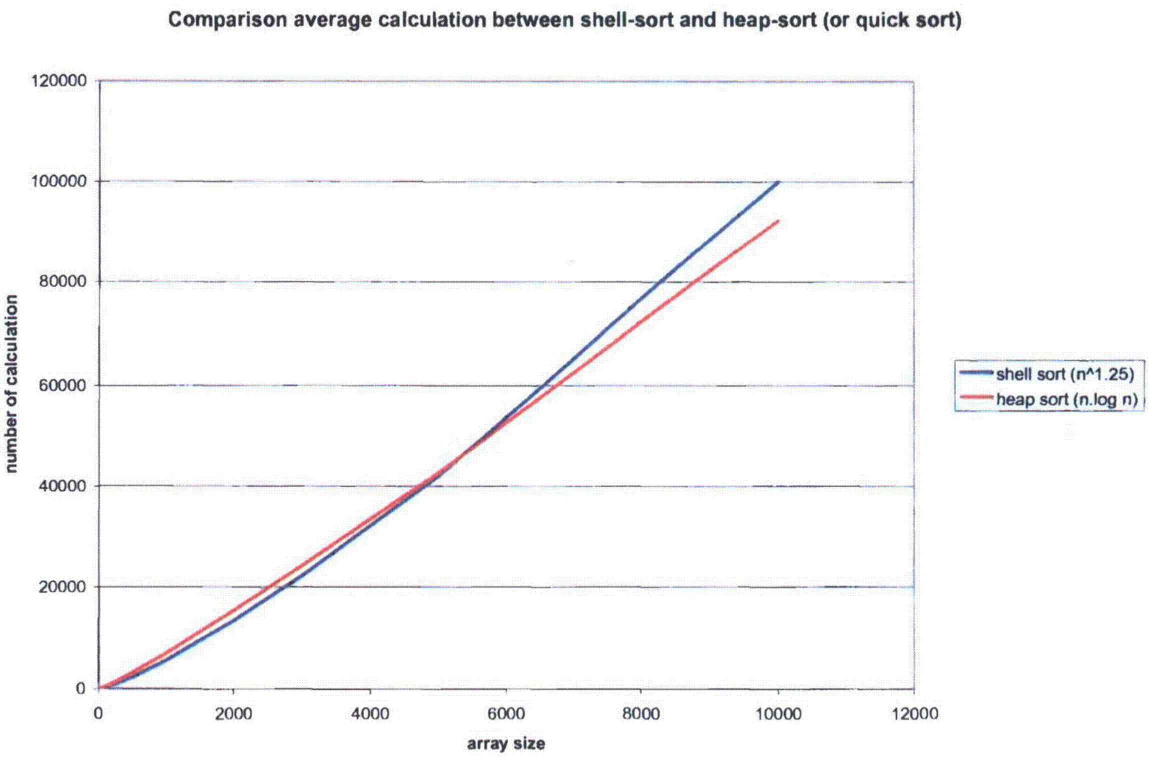


Figure 10. Comparison of Average Number of Operations for Shell Sort and Heap Sort (or Quick Sort) Methods

These convergences are of course average and can be different for the worst case or best case scenarios.

Both algorithms are available in numerical recipes. Shell sort is the simplest to implement, and most of the data to sort are between a few hundred and a few thousands. Therefore, the shell sort method has been considered as the most interesting sorting method in our case. Even if the number of data is around 10^4, the loss of time is negligible (the code generally runs in less than a minute).

Checking has been performed to verify that shell sort can deal with draws in the values sorted. The affirmative results confirmed shell sort as a good method in our case.

4.3 Control Logic

Given the straightforward nature of this design, a formal descriptive emphasis of its control logic is deemed inappropriate for this software design.

4.4 Data Structures

Based on the algorithm described in Section 4.1, only simple data types of variables and arrays are considered.

4.5 Control Flow

Based on the steps described in Section 4.1, a flow diagram for EXDOC_LA is developed that can be translated into FORTRAN coding. The flow diagram is provided in Appendix A. The flow diagram represents an expected implementation of the software structure outlined in Section 4.

The functional requirements, as specified in the RD, are addressed in the flow diagram along with their unique identifier.

4.6 Data Flow

Appendix A shows a flow diagram for EXDOC_LA. This diagram provides a visual representation of the flow of data through the software.

5. INPUT/OUTPUT

5.1 Input Ranges

5.1.1. Input copied in "info.dat" (or equivalent name)

The list below shows all the parameters that may be requested for a specific run (depending on the scenario selected) used to create the "info.dat" file (or equivalent file for other scenarios). The code will accept any reasonable value for each of these parameters (as described below). However, these values are specific to the Goldsim run being analyzed and only the use of the correct value will lead to expected results.

- A **prefix** (string of maximum 10 characters): this prefix is used to determine the names of the input data. It is also used to create the names of the output files. The prefix value depends on the prefix name chosen.
- **Lambda_filename** (string of maximum 20 characters) is the name of the file storing the sample on the frequency of events. It depends on the filename chosen for saving lambda values.
- **Tevent_filename** (string of maximum 20 characters) is the name of the file storing the different time of event available. It depends on the filename chosen for saving tevent values.
- **Ampli_filename** (string of maximum 20 characters) is the name of the file storing the different amplitude of event available. It depends on the filename chosen for saving amplitude values.
- **Bin_filename** (string of maximum 20 characters) is the name of the file storing the fraction of the repository attributed to each percolation bin. It depends on the filename chosen for saving bin fraction values.
- **Dripcd_filename** (string of maximum 20 characters) is the name of the file storing the fraction of repository under dripping condition, per LHS element and per percolation bin. It depends on the filename chosen for saving drip fraction values.

- **WP_filename** (string of maximum 20 characters) is the name of the file storing the distribution of WP in a certain condition, per WP type. It depends on the filename chosen for saving Wp type fractions values.
- **Quant_filename** (string of maximum 20 characters) is the name of the file listing the quantiles desired for the statistical analysis. It depends on the filename chosen for saving quantile values.
- **Law_A1_filename** (string of maximum 20 characters) is the name of the file containing the distribution law relative to the amplitude of the event. It depends on the filename chosen for saving distribution on amplitude.
- **Disruptive flag** (integer of maximum 2 digits) is a flag used for the library EXDOC_LA.DLL. It is created automatically by the GUI.
- **Sample_size** (integer of maximum 7 digits) corresponds to the sample size for the epistemic uncertainty. It should be equal to the epistemic sample size used in the Goldsim calculation.
- **Input_timestep** (integer of maximum 5 digits) indicates the total number of timesteps considered in the GoldSim calculation. It should be equal to the number of timesteps considered in the Goldsim calculation.
- **Nb_bins** (integer of maximum 3 digits) indicates the number of percolation bins considered. It should be equal to the number of bins considered in the Goldsim calculation.
- **Nb_wps** (integer of maximum 3 digits) indicates the number of WP type considered. It should be equal to the number of WPs type considered in the Goldsim calculation.
- **Nb_aleatory** (integer of maximum 3 digits) number of aleatory files considered. It should be equal to the number of aleatory parameters considered in the Goldsim calculation.
- **Aleatory_size** (set of integer of maximum 5 digits) aleatory sample size for each of the files considered. It should be equal to the aleatory sample size considered in the Goldsim calculation
- **Nb_input_tevent** (integer of maximum 5 digits) indicates the total number of times of events considered. It should be equal to the number of time of events for which Goldsim calculations have been performed.
- **Nb_input_amplitude** (integer of maximum 5 digits) indicates the total number of amplitudes of events considered. It should be equal to the number of amplitudes for which the Goldsim calculations have been performed.
- **Min_tevent** (real in free floating format) indicates the minimum time of event considered. It should be equal to the minimum time of event used in the Goldsim calculation.
- **Max_tevent** (real in free floating format) indicates the maximum time of event considered. It should be equal to the maximum time of event used in the Goldsim calculation.

- **Min_amplitude** (real in exponential format 12.3) indicates the minimum amplitude of event considered. It should be equal to the minimum amplitude of event used in the Goldsim calculation.
- **Max_amplitude** (real in exponential format 12.3) indicates the maximum amplitude of event considered. It should be equal to the maximum amplitude of event used in the Goldsim calculation.
- **Nb_law_A1** (integer of maximum 5 digits) indicates the number of values in the distribution characterizing the Fractional Surface Area Damaged. It should be equal to the number of quantiles used in the distribution of Surface Area Damaged.
- **Nb_law_A2** (integer of maximum 5 digits) indicates the number of values in the distribution characterizing the number of WP destroyed. It should be equal to the number of quantiles used in the distribution of the number of Wps destroyed.
- **Nb_quant** (integer of maximum 3 digits) indicates the number of quantiles considered for the statistical analysis. It should be equal to the number of quantiles selected in the file referred by Quant_filename.
- **Data_saved** (integer of maximum 7 digits) indicates the LHS realization for which some values will be saved. It should be no bigger than the epistemic sample size.
- **Analysis_flag** (integer of maximum 2 digits) indicates the kind of analysis to perform: 1=expected dose; 2= CCDF; 3=both. This is selected in the GUI by checking boxes relative to the analysis expected. At least one box should be checked.
- **Dshield_incl** (integer of maximum 2 digits) indicates whether the drip shield failure is included (=1) or not (=0) in the analysis. This corresponds to a box to check in the GUI. The box can be checked or unchecked depending on the analysis expected.
- **Wp_woshield_filename** (string of maximum 20 characters) is the name of the file storing the expected probability of drip shield failure through time. This should correspond to the filename used for saving the expected probability of drip shield failure.
- **Nbwpd_woshield** (set of reals with unspecified format) indicates, for each WP type, the number of WPs destroyed once the Drip Shield has failed. This number has to be positive and no bigger than the number of WPs of this type in the repository.
- **Log_info** (integer of maximum 3 digits) is an indicator for debugging or local analysis.. This value is used to save some information in the log file. Currently, if log_info is greater than 3, the positions of quantiles (in the sample file) are saved. If log_info >4, the accuracy of CCDF, for each sample element is saved. Finally, for log_info > 5, the list of dose input files read is saved.

5.1.2. Input copied in "expc.dat" (or equivalent name)

The list below shows all the parameters that may be requested for a specific run (depending on the scenario selected) used to create the "expc.dat" file (or equivalent file for other scenarios). The code will accept any reasonable value for each of these parameters (as described below). However, these values may be limited in range by the Goldsim run begin analyzed and only the use of the correct value will lead to expected results.

- **Expec_amplitude** (real in exponential format 12.3) is the expected value for the amplitude of the event. It is used only for the igneous intrusive case, in order to have a faster and more accurate calculation (instead of calculating it from the amplitude law). This number has to be consistent with the distribution of amplitude and its value should be equal to the expected amplitude for the run specified.

- **Min_time_interp** (real in free floating format) is the minimum time-step considered in this analysis. This number has to be positive and smaller than the number Max_time_interp.

- **Max_time_interp** (real in free floating format) is the maximum time-step considered in this analysis. This number should be bigger than Min_time_interp and no bigger than the maximum time considered in the analysis.

- **NB_time** (integer of maximum 5 digits) is the number of time-steps considered in this analysis. This number determines internal array sizes and should be big enough to perform the analysis, but not too big so that excessive memory is used or the calculation time is increased to an unreasonable time. A value of 10^4 or bigger is generally not recommended.

- **NB_tevent** (integer of maximum 5 digits) is the number of times of events considered in this analysis. This number determines internal array sizes and should be big enough to perform the analysis, but not too big so that excessive memory is used or the calculation time is increased to an unreasonable time. A value of 10^4 or bigger is generally not recommended.

- **NB_amplitude** (integer of maximum 5 digits) is the number of amplitude-steps considered between two values defined in the law on the amplitude in this analysis. In other words, it is the discretization used between two amplitudes defined in the law file, in order to calculate the terms bordered in red in Eq. 2. This number can be on the order of 10^4. However, a value on the order of 10^2 has shown good results.

- **NB_tevent_saved** (integer of maximum 5 digits) is the number of time of events considered for the dose file (description of dose file below). ***Note:*** *the value NB_tevent_saved must be lower or equal to NB_tevent then a divisor of NB_tevent will give the best distribution of doses saved (even if any other number will work).* This number depends on the number of values saved in a dose file. A small value will lead to poor accuracy, while a big value will create a big file. A value on the order of 10^2 should be reasonable.

- **Sum_over_WPs** (integer of maximum 2 digits) indicates whether the analysis is done by summing the results amongst WP types (=1) or not (=0). This corresponds to a box that can be checked in the GUI.

- **Sum_over_bins** (integer of maximum 2 digits) indicates whether the analysis is done by summing the results among percolation bins (=1) or not (=0). This corresponds to a box that can be checked in the GUI.

- **Sum_over_drpcds** (integer of maximum 2 digits) indicates whether the analysis is done by summing the results among dripping conditions (=1) or not (=0). This corresponds to a box that can be checked in the GUI.
- **Regulatory_a_val** (integer of maximum 2 digits) indicates the regulatory value used when integrating over aleatory uncertainty (1= mean, 2=quantile, 3=min(mean, quantile)). This corresponds to a list in which one value must be selected (the first instance is selected by default) in the GUI.
- **Regulatory_e_val** (integer of maximum 2 digits) indicates the regulatory value used when integrating over epistemic uncertainty (1= mean, 2=quantile, 3=min(mean, quantile)). This corresponds to a list in which one value must be selected (the first instance is selected by default) in the GUI.
- **A_quantile** (real of unspecified format) quantile used for determining regulatory value on aleatory uncertainty. This value has to be a real between 0.0 and 1.0.
- **E_quantile** (real of unspecified format) quantile used for determining regulatory value on epistemic uncertainty. This value has to be a real between 0.0 and 1.0.

5.1.3. Input copied in "ccdf.dat" (or equivalent name)

The list below shows all the parameters that may be requested for a specific run (depending on the scenario selected) used to create the "ccdf.dat" file (or equivalent file for other scenarios). The code will accept any reasonable value for each of these parameters (as described below). However, these values may be limited in range by the Goldsim run being analyzed and only the use of the correct value will lead to expected results.

- **Time_Saved** (real in free floating format) is the time at which the CCDF must be calculated. This value cannot be lower than the minimum time considered, nor bigger than the maximum time considered.
- **NB_tevent_ccdf** (integer of maximum 5 digits) is the number of times of events considered for the CCDF. This value determines the quality of the discretization. A small value leads to poor accuracy, while a large value uses more memory and will increase the calculation time.
- **NB_ampli_ccdf** (integer of maximum 5 digits) is the number of amplitude-steps considered in the CCDF. This value determines the quality of the discretization. A small value leads to poor accuracy, while a large value uses more memory and will increase the calculation time.
- **Lin_log_quant** (integer of maximum 2 digits) is a flag for the discretization method used for the amplitude of the event. A value of 0 will lead to a linear discretization, a value of 1 for a logarithmic, and a value of 2 for a discretization based on the quantiles of the probability law. This value has to be 0, 1 or 2.
- **Stats_CCDF_Discr** (integer of maximum 3 digits) indicates the number of values considered in the discretization of the output, in order to calculate statistics on the CCDF. This value determines the quality of the discretization for the statistics. A small

value leads to poor accuracy, while a large value uses more memory and will increase the calculation time.

- **Stats_CCDF_meth** (integer of maximum 3 digits) indicates the discretization method used for calculating statistics on CCDF (0= linear, 1=logarithmic). This value must be 0 or 1.

5.2 Output Ranges

The limitations of EXDOC_LA calculated outputs are described in the output file descriptions of Section 5.5.

5.3 Parameter Files

5.3.1 EXDOC_LA Input File Contents

A number of requirements listed in the Requirements Document refer to input files that contain information on option settings that inform the program what calculations to perform and what output to produce. These input files and their expected contents are shown in Table 5.1 below, and are further described in this section.

Table 5.1. EXDOC_LA Input File Contents

Input File Name	Contents of Input File
info.dat	The parameters in info.dat: • **prefix** (string of maximum 10 characters) • **Lambda_filename** (string of maximum 20 characters) • **Tevent_filename** (string of maximum 20 characters) • **Ampli_filename** (string of maximum 20 characters) • **Quant_filename** (string of maximum 20 characters) • **Law_A1_filename** (string of maximum 20 characters) • **Disruptive flag** (integer of maximum 2 digits) • **Sample_size** (integer of maximum 7 digits) • **Input_timestep** (integer of maximum 5 digits) • **Nb_input_tevent** (integer of maximum 5 digits) • **Nb_input_amplitude** (integer of maximum 5 digits) • **Min_tevent** (real in free floating point format) • **Max_tevent** (real in free floating point format) • **Min_amplitude** (real in exponential format 12.3) • **Max_amplitude** (real in exponential format 12.3) • **Nb_law_A1** (integer of maximum 5 digits) • **Nb_quant** (integer of maximum 3 digits) • **Data_saved** (integer of maximum 7 digits) • **Analysis_flag** (integer of maximum 2 digits) • **Log_info** (integer of maximum 3 digits)

Input File Name	Contents of Input File
expc.dat	The parameters in expc.dat: • **Expec_amplitude** (real in exponential format 12.3) • **Min_time_interp** (real in free floating point format) • **Max_time_interp** (real in free floating point format) • **NB_time** (integer of maximum 5 digits) • **NB_tevent** (integer of maximum 5 digits) • **NB_amplitude** (integer of maximum 5 digits) • **NB_tevent_saved** (integer of maximum 5 digits) • **Regulatory_e_val** (integer of maximum 2 digits) • **E_quantile** (real of unspecified format) – necessary only if Regulatory_e_val is equal to 1 or 2
ccdf.dat	The parameters in ccdf.dat: • **Time_Saved** (real in free floating point format) • **NB_tevent_ccdf** (integer of maximum 5 digits) • **NB_ampli_ccdf** (integer of maximum 5 digits) • **Lin_log_quant** (integer of maximum 2 digits) • **Stats_CCDF_Discr** (integer of maximum 3 digits) • **Stats_CCDF_Meth** (integer of maximum 3 digits)
info_mc.dat	The parameters in info_mc.dat: • **prefix** (string of maximum 10 characters) • **Quant_filename** (string of maximum 20 characters) • **Sample_size** (integer of maximum 7 digits) • **Nb_Input_timestep** (integer of maximum 5 digits) • **Number_files** (integer of maximum 5 digits) • **Aleatory_size** (set of integers of maximum 5 digits – number of integers equal to Number_files) • **Nb_quant** (integer of maximum 3 digits) • **Data_saved** (integer of maximum 7 digits) • **Analysis_flag** (integer of maximum 2 digits) • **Log_info** (integer of maximum 3 digits)
expc_mc.dat	The parameters in expc_mc.dat: • **Regulatory_a_val** (integer of maximum 2 digits) • **Regulatory_e_val** (integer of maximum 2 digits) • **A_quantile** (real of unspecified format) – necessary only if Regulatory_a_val = 2 or 3 • **E_quantile** (real of unspecified format) – necessary only if Regulatory_e_val =2 or 3
ccdf_mc.dat	The parameters in ccdf_mc.dat: • **Time_Saved** (real in free floating point format) • **Stats_CCDF_Discr** (integer of maximum 3 digits) • **Stats_CCDF_Meth** (integer of maximum 3 digits)

Input File Name	Contents of Input File
info_cv.dat	The parameters in info_cv.dat: • **prefix** (string of maximum 10 characters) • **Lambda_filename** (string of maximum 20 characters) • **Bins_filename** (string of maximum 20 characters) • **Dripfr_filename** (string of maximum 20 characters) • **WP_filename** (string of maximum 20 characters) • **Quant_filename** (string of maximum 20 characters) • **Sample_size** (integer of maximum 7 digits) • **Nb_time** (integer of maximum 5 digits) • **Nb_bins** (integer of maximum 3 digits) • **Nb_wps** (integer of maximum 3 digits) • **Nb_quant** (integer of maximum 3 digits) • **Analysis_flag** (integer of maximum 2 digits) • **Log_info** (integer of maximum 3 digits)
expc_cv.dat	The parameters in expc_cv.dat: • **Sum_over_wps** (integer of maximum 2 digits) • **Sum_over_bins** (integer of maximum 2 digits) • **Sum_over_drpcds** (integer of maximum 2 digits) • **Regulatory_e_val** (integer of maximum 2 digits) • **E_quantile** (real of unspecified format) - necessary only if Regulatory_e_val =2 or 3
ccdf_cv.dat	The parameters in ccdf_cv.dat: • **Time_Saved** (real in free floating point format) • **NB_point_ccdf** (integer of maximum 5 digits) • **Stats_CCDF_Discr** (integer of maximum 3 digits) • **Stats_CCDF_Meth** (integer of maximum 3 digits)

Input File Name	Contents of Input File
info_mct.dat	The parameters in info_mct.dat: • **prefix** (string of maximum 10 characters) • **Lambda_filename** (string of maximum 20 characters) • **Tevent_filename** (string of maximum 20 characters) • **Ampli_filename** (string of maximum 20 characters) • **Quant_filename** (string of maximum 20 characters) • **Law_a1_filename** (string of maximum 20 characters) • **Sample_size** (integer of maximum 7 digits) • **Input_timestep** (integer of maximum 5 digits) • **Nb_input_tevent** (integer of maximum 5 digits) • **Nb_input_ampli** (integer of maximum 5 digits) • **Aleatory_sample_size** (integer of maximum 5 digits) • **Min_tevent** (real in free floating point format) • **Max_tevent** (real in free floating point format) • **Min_amplitude** (real in exponential format 12.3) • **Max_amplitude** (real in exponential format 12.3) • **Nb_law_A1** (integer of maximum 5 digits) • **Nb_quant** (integer of maximum 3 digits) • **Data_saved** (integer of maximum 7 digits) • **Analysis_flag** (integer of maximum 2 digits) • **Log_info** (integer of maximum 3 digits)
expc_mct.dat	The parameters in expc_mct.dat: • **Expec_amplitude** (real in exponential format 12.3) • **Min_time_interp** (real in free floating point format) • **Max_time_interp** (real in free floating point format) • **NB_time** (integer of maximum 5 digits) • **NB_tevent** (integer of maximum 5 digits) • **NB_tevent_saved** (integer of maximum 5 digits) • **Regulatory_e_val** (integer of maximum 2 digits) • **E_quantile** (real of unspecified format)- necessary only if Regulatory_e_val = 2 or 3
ccdf_mct.dat	The parameters in ccdf_mct.dat: • **Time_Saved** (real in free floating point format) • **NB_point_ccdf** (integer of maximum 5 digits) • **Stats_CCDF_Discr** (integer of maximum 3 digits) • **Stats_CCDF_Meth** (integer of maximum 3 digits)

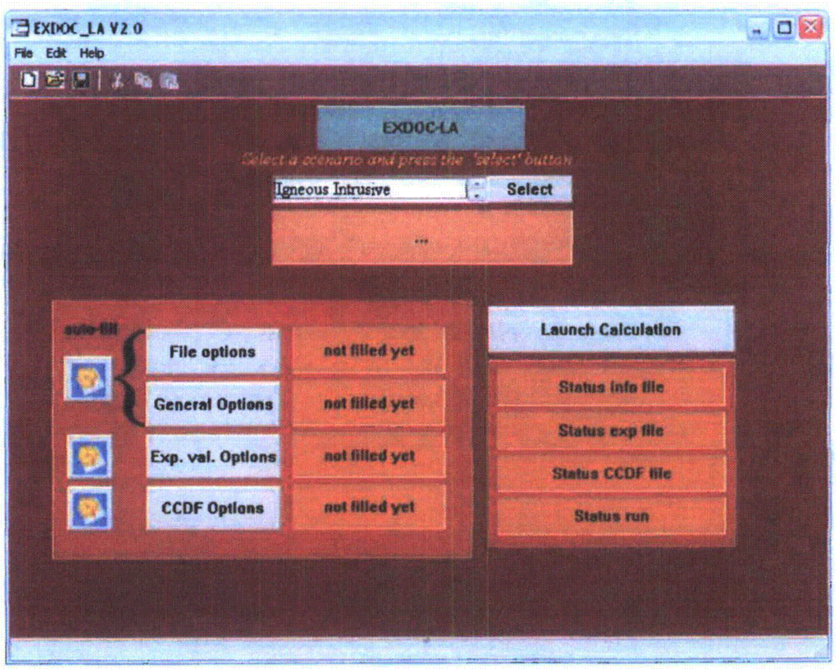
Input File Name	Contents of Input File
info_fd.dat	The parameters in info_fd.dat: • **prefix** (string of maximum 10 characters) • **Tevent_filename** (string of maximum 20 characters) • **Ampli_filename** (string of maximum 20 characters) • **Bins_filename** (string of maximum 20 characters) • **Dripfr_filename** (string of maximum 20 characters) • **WP_filename** (string of maximum 20 characters) • **Quant_filename** (string of maximum 20 characters) • **prefix_ampli** (string of maximum 20 characters) • **Sample_size** (integer of maximum 7 digits) • **Input_timestep** (integer of maximum 5 digits) • **Nb_bins** (integer of maximum 3 digits) • **Nb_WPs** (integer of maximum 3 digits) • **Nb_input_tevent** (integer of maximum 5 digits) • **Nb_input_ampli** (integer of maximum 5 digits) • **Min_tevent** (real in free floating point format) • **Max_tevent** (real in free floating point format) • **Min_amplitude** (real in exponential format 12.3) • **Max_amplitude** (real in exponential format 12.3) • **Nb_law_A1** (integer of maximum 5 digits) • **Nb_law_A2** (integer of maximum 5 digits) • **Nb_quant** (integer of maximum 3 digits) • **Data_saved** (integer of maximum 7 digits) • **Analysis_flag** (integer of maximum 2 digits) • **Log_info** (integer of maximum 3 digits)
expc_fd.dat	The parameters in expc_fd.dat: • **Min_time_interp** (real in free floating point format) • **Max_time_interp** (real in free floating point format) • **NB_time** (integer of maximum 5 digits) • **NB_tevent** (integer of maximum 5 digits) • **NB_amplitude** (integer of maximum 5 digits) • **Sum_over_wps** (integer of maximum 2 digits) • **Sum_over_bins** (integer of maximum 2 digits) • **Sum_over_drpcds** (integer of maximum 2 digits) • **Regulatory_e_val** (integer of maximum 2 digits) • **E_quantile** (real of unspecified format) – necessary only if Regulatory_e_val = 2 or 3
ccdf_fd.dat	The parameters in ccdf_fd.dat: • **Time_Saved** (real in free floating point format) • **NB_point_ccdf** (integer of maximum 5 digits) • **Stats_CCDF_Discr** (integer of maximum 3 digits) • **Stats_CCDF_Meth** (integer of maximum 3 digits)

Input File Name	Contents of Input File
info_se.dat	The parameters in info_se.dat: • **prefix** (string of maximum 10 characters) • **Lambda_filename** (string of maximum 20 characters) • **Tevent_filename** (string of maximum 20 characters) • **Ampli_filename** (string of maximum 20 characters) • **Quant_filename** (string of maximum 20 characters) • **Law_a1_filename** (string of maximum 20 characters) • **Law_a2_filename** (string of maximum 20 characters) • **Sample_size** (integer of maximum 7 digits) • **Input_timestep** (integer of maximum 5 digits) • **Nb_input_tevent** (integer of maximum 5 digits) • **Nb_input_ampli** (integer of maximum 5 digits) • **Min_tevent** (real in free floating point format) • **Max_tevent** (real in free floating point format) • **Min_amplitude** (real in exponential format 12.3) • **Max_amplitude** (real in exponential format 12.3) • **Nb_law_A1** (integer of maximum 5 digits) • **Nb_law_A2** (integer of maximum 5 digits) • **Nb_quant** (integer of maximum 3 digits) • **Data_saved** (integer of maximum 7 digits) • **Analysis_flag** (integer of maximum 2 digits) • **Log_info** (integer of maximum 3 digits)
expc_se.dat	The parameters in expc_se.dat: • **Expec_amplitude** (real in exponential format 12.3) • **Min_time_interp** (real in free floating point format) • **Max_time_interp** (real in free floating point format) • **NB_time** (integer of maximum 5 digits) • **NB_tevent** (integer of maximum 5 digits) • **NB_amplitude** (integer of maximum 5 digits) • **NB_tevent_saved** (integer of maximum 5 digits) • **Regulatory_e_val** (integer of maximum 2 digits) • **E_quantile** (real of unspecified format) if Regulatory_e_val = 2 or 3
ccdf_se.dat	The parameters in ccdf_se.dat: • **Time_Saved** (real in free floating point format) • **NB_point_ccdf** (integer of maximum 5 digits) • **Stats_CCDF_Discr** (integer of maximum 3 digits) • **Stats_CCDF_Meth** (integer of maximum 3 digits)

Input File Name	Contents of Input File
info_tr.dat	The parameters in info_tr.dat: • **prefix** (string of maximum 10 characters) • **Sample_size** (integer of maximum 7 digits) • **Nb_time** (integer of maximum 5 digits) • **Total_aleatory** (integer of maximum 7 digits) • **Number_aleatory** (integer of maximum 7 digits) • **Order_aleatory** (set of integers of unspecified format) – the number of integers is equal to **Number_aleatory** • **Size_aleatory** (set of integers of unspecified format) – the number of integers is equal to **Number_aleatory** • **Position_aleatory** (set of integers of unspecified format) – the number of integers is equal to **Size_aleatory(I)** for each line I, and there are **Number_aleatory** lines. • **Log_info** (integer of maximum 3 digits)

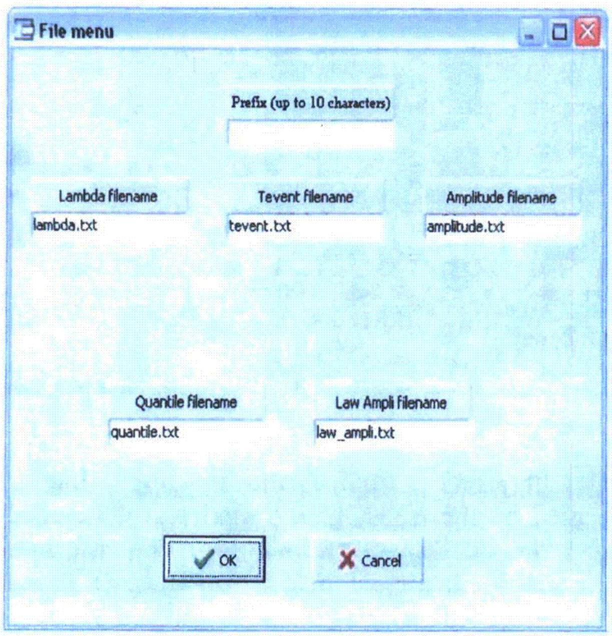
5.3.2 EXDOC_LA GRAPHICAL USER INTERFACE

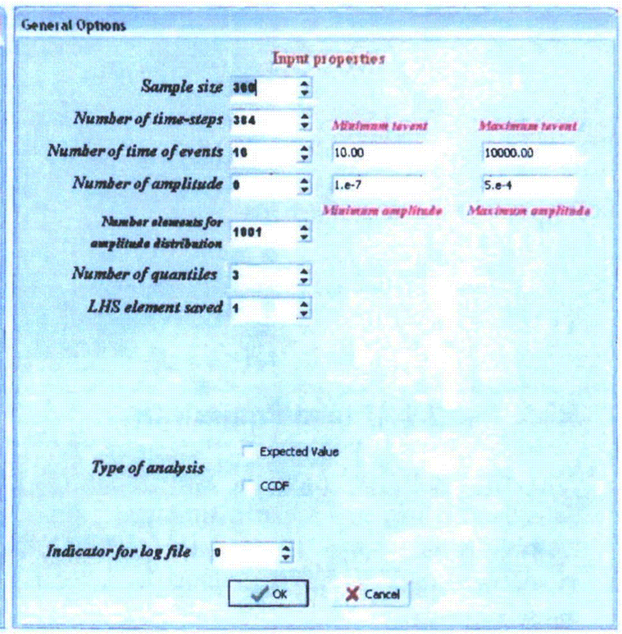
Each parameter file is created using the EXDOC_LA Graphical User Interface (GUI). The GUI allows the user to create these files based on a selected scenario and to launch the appropriate library to perform the calculations. An example of the basic GUI look is displayed below.



5.3.3 "info.dat" (and equivalents)

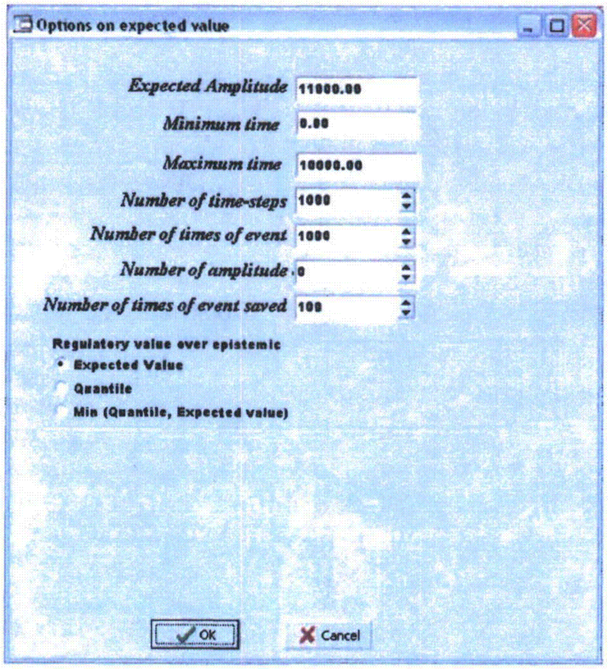
The file "info.dat" (and its equivalents for the other libraries) is used by the libraries to know the general options of a specific calculation. It is created by the EXDOC_LA GUI and developed in Delphi 2006. Two windows are used to display the necessary information. The information available in each window depends on the scenario selected (example displayed below for igneous intrusive modeling case).





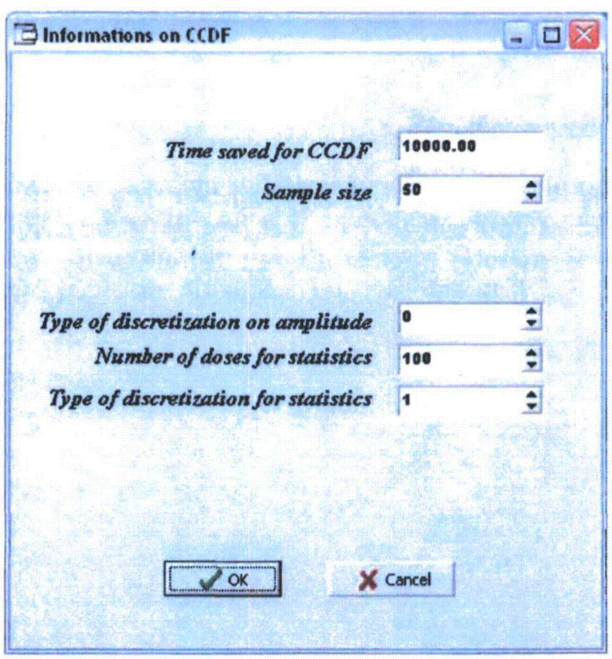
5.3.4 "expc.dat" (and Equivalents)

The file "expc.dat" (and its equivalents for the other libraries) is used by the libraries to know the options relating to expected dose calculation. It is created by the EXDOC_LA GUI and developed in Delphi 2006. One window is used to display the necessary information. The information available depends on the scenario selected (example displayed below for igneous intrusive modeling case).



5.3.5 "ccdf.dat" (and Equivalents)

The file "ccdf.dat" (and its equivalents for other libraries) is used by the libraries to know the options relating to CCDF estimation. It is created by the EXDOC_LA GUI and developed in Delphi 2006. One window is used to display the necessary information. The information available depends on the scenario selected (example displayed below for igneous intrusive modeling case).



5.4 Input Files

Identifiers accompanying the input descriptions below, such as (IR-01), refer to requirements as specified in the RD. Besides the information files containing all of the parameters controlling the calculation, the code needs several other files in order to run. These include the following:

- The input files (saved as text files) containing all the doses calculated via GoldSim [DIRS 169844]
- A text file containing all the sampled values of the frequency of the disruptive event
- A text file containing all the time of events considered
- A text file containing all the amplitude of events (i.e., number of WPs or fraction of surface area damaged) considered
- A text file containing the probability distribution associated with the amplitude of the event
- A text file containing all the quantiles desired for the statistical calculation
- A text file containing the fraction each percolation bin represents in the repository
- A text file containing the variation of dripping condition for each epistemic set and each percolation bin
- A text file containing the fraction of total WPs represented by each WP type.

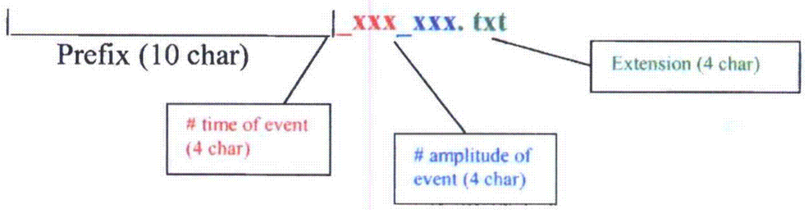
5.4.1 Dose Files

These files contain the data calculated by GoldSim [DIRS 169844] (IR-01).

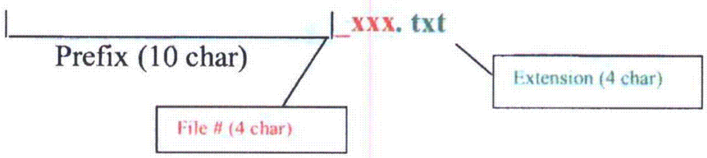
The data considered are a time-dependent uncertain variable. GoldSim [DIRS 169844] saves the data in the following way:

- The first line is a column indicator, letter indented (i.e., 1st col. ="A"; 2nd col. = "B" ...).
- The second line is the column title beginning with the time of event and realization number.
- The third line and below are the data starting with the corresponding time in the first column and the resulting dose at this time for each realization.

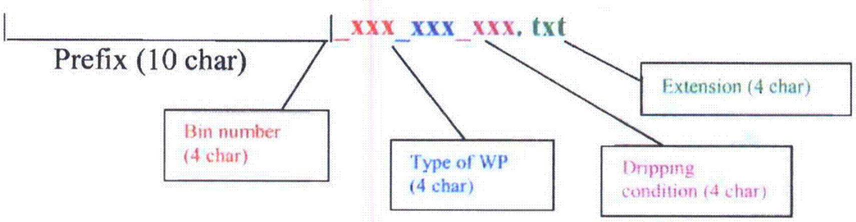
For Igneous Intrusive calculations, the GoldSim [DIRS 169844] calculation is performed for each time of event considered and each amplitude of event considered. The format of each file name must be as follows:



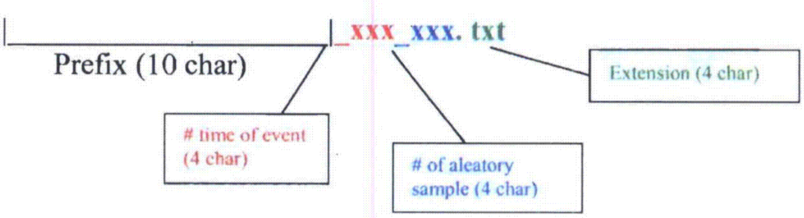
For Seismic GMD (peak dose), one of several Monte Carlo files will be available. The format of each file name must be as follows:



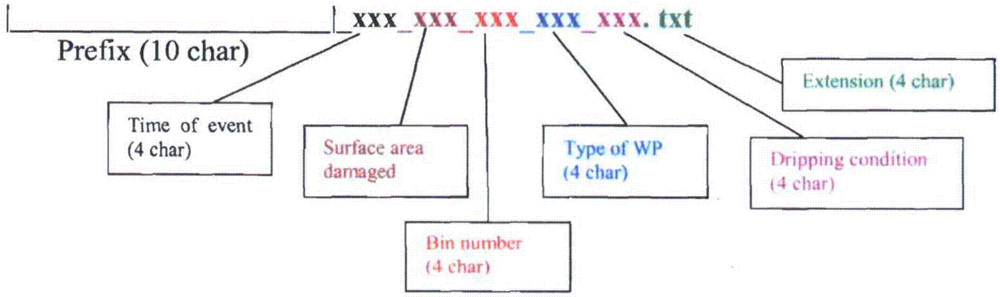
The Nominal early failure modeling case needs separation based on dripping condition, WP type, and bins location. The format of each file name must be as follows:



The Igneous Eruptive modeling case needs separation between time of event and aleatory sample considered in GoldSim [DIRS 169844]. The format of each file name must be as follows:



The Seismic Fault Displacement needs the most complex name, as it needs separation between locations (bins numbers and dripping conditions), WP type, time of event, and fraction of surface area damaged. A valid filename would be:



If the file naming convention is not respected, the library EXDOC_LA TR is used to fulfill this requirement.

5.4.2 Lambda File

The lambda file contains all the values sampled of the disruptive event frequency (IR-2). This file is composed of one column and *n* lines (*n* representing the epistemic sample size).

Used by all libraries except EXDOC_LA_MC, EXDOC_LA_FD, and EXDOC_LA_TR.

5.4.3 Time of Event File

The time of event file lists event times for which the calculations have been done (IR-3). Each time of event is copied (as a real in regular format) in each row.

Note: Event times are supposed to be sorted in increasing order.

Used by EXDOC_LA, EXDOC_LA_MCT, and EXDOC_LA_FD.

5.4.4 Amplitude File

The amplitude file contains a list of amplitudes for which the calculations have been done (IR-4). Each row has one amplitude (as a real in regular format).

Note: Amplitudes must be sorted in increasing order.

Used by EXDOC_LA and EXDOC_LA_FD.

5.4.5 Quantile File

The quantile file contains the list of quantiles requested for the statistical analysis (IR-5).

Note: Quantiles do not need to be sorted.

Used by all libraries except EXDOC_LA_TR.

5.4.6 Law on the Amplitude File

The amplitude law file contains the CDF associated with the probability on the amplitude (IR-6). It consists of $2n$ columns (n representing the epistemic sample size):

- The odd columns contain the probability to be below or equal to a certain threshold dose.
- The event columns contain the value of the threshold dose.

Note: By default, cumulative distributions are supposed to be sorted.

Used by all libraries, except EXDOC_LA_TR and EXDOC_LA_MC.

5.4.7 Bins Fractions File

The bins fractions file contains the fraction of repository covered by each percolation bin (IR-7). It consists in 1 column of fraction values. The sum of fractions should be equal to 1.

Used by EXDOC_LA_FD and EXDOC_LA_CV.

5.4.8 Dripping Condition Fractions File

The dripping fractions file contains the fraction of dripping for each percolation bin in the repository (IR-8). It consists in b columns of size n (b representing the number of bins and n the epistemic sample size).

Used by EXDOC_LA_FD and EXDOC_LA_CV.

5.4.9 WP Fractions File

The WP fractions file contains the fraction of each WP type in the repository (IR-9). It consists in 1 column of fraction values. The sum of fractions should be equal to 1.

Used by EXDOC_LA_FD and EXDOC_LA_CV.

5.4.10 Drip Shield Failure Probability File

The drip shield failure probability file contains the probability of having a drip shield failure at a given time (IR-10). It consists of 2 columns: the first column corresponds to the time step, while the second corresponds to the probability of failure at this timestep.

Used by EXDOC_LA_FD and EXDOC_LA_CV.

5.5 Output Files

Identifiers accompanying the output descriptions below, such as (OR-01), refer to requirements as specified in the RD.

ALL THE OUTPUT FILES NAMES ARE CREATED AUTOMATICALLY BASED ON THE PREFIX GIVEN IN THE "INFO.DAT" FILE.

The code will generate the following files:

- A log file giving some information about the running (warnings and debug information)
- A text file containing all the expected doses
- A text file containing the statistics on the expected doses
- A text file containing a fraction of the interpolated doses for a given LHS realization
- A text file containing the CCDFs of doses at a given time
- A text file containing the statistics of the CCDFs at a given time
- A text file containing a mapping of the dose for a given LHS realization at a given time.

The first file is always created. The second and third files are created when an expected dose calculation is performed. The last four files are created when a CCDF calculation is requested.

5.5.1 Log File

The log filename is obtained by concatenating the prefix with the string "_log.txt" (OR-1). This file, always created, contains some information about the run. For instance:

- Time spent in each part of the code
- Warning if any extrapolation is needed
- Giving information about an unexpected stop of the code.

5.5.2 Expected Doses

The expected dose filename is obtained by concatenating the prefix with the string "_exp.txt" (OR-2).

This file contains the expected doses calculated for each set of epistemic parameters. The format chosen is consistent with GoldSim [DIRS 169844]. Indeed, a big matrix is saved. The first column contains the different timesteps.

Each remaining column contains the result of the integration over the aleatory uncertainty at this time and for the corresponding LHS realization.

Note: This text file is generated if the expected dose calculation has been requested in the info file. Several files can be created with EXDOC_LA_CV and EXDOC_LA_FD, depending on the options chosen.

5.5.3 Statistics on the Expected Doses

The statistics on the expected dose filename is obtained by concatenating the prefix with the string "_stat.txt" (OR-3).

This file contains statistics on the expected doses calculated for each set of epistemic parameters. The format chosen is consistent with GoldSim [DIRS 169844]. A matrix is saved. The first column contains the different timesteps.

The second column contains the regulatory value, which could be the average, a quantile, or the minimum of the average and a quantile. The third column displays the average value of the expected doses at this time. Starting at the fourth column, all the quantiles requested are saved.

Note: This text file is generated if the expected dose calculation has been requested in the information file. Several files can be created with EXDOC_LA_CV and EXDOC_LA_FD, depending on the options chosen.

5.5.4 Doses for a Given LHS Realization

The doses at an LHS realization filename is obtained by concatenating the prefix with the string "_d", the realization number (7 digits integer), and the string ". txt" (OR-4).

In this file, the integrated doses over the amplitude of event are saved for a given LHS realization. A matrix is saved. The first column contains the different timesteps. Each remaining column represents one integrated dose for a given time of event.

Note: This file is NOT created by EXDOC_LA_CV and EXDOC_LA_FD.

5.5.5 CCDF at a Given Time

The CCDF filename is obtained by concatenating the prefix with the string "_ccdf", the time of interest (7 digits integer), and the string ". txt" (OR-5).

In this file, CCDFs at the chosen time are saved. The file is composed of $2n$ columns, where n designates the sample size on the epistemic uncertainty. Each odd column gives the different values of dose found for the particular LHS realization. Each even column gives the corresponding probability to have a dose greater than or equal to this value.

5.5.6 Statistics on CCDF at a Given Time

Statistics on the CCDF filename is obtained by concatenating the prefix with the string "_stat", the time of interest (7 digits integer), and the string ". txt" (OR-6).

In this file, statistics on CCDFs are saved. The first column contains a discretization on the range of possible doses.

Column 2 gives the average probability over all CCDFs. Starting from Column 3, all of the quantiles on the CCDFs are defined in the quantile file.

Note: Since the dose has a wide range of value and, as commonly observed in risk analysis, the biggest values have a very low probability, a log-discretization has been chosen to treat the dose.

5.5.7 Mapping on the Time of Event and Amplitude

The mapping of one CCDF filename is obtained by concatenating the prefix with the string "_map", the time of interest (7 digits integer), and the string ". txt". Here, the realization number is not added to avoid a long name (OR-7).

This file is composed of three columns. The first column contains the discretization on time of event (linear). The second contains the discretization on amplitude (either linear, logarithmic, or based on quantile, depending on the choice made by the user). The third and last column gives the value of dose for the given time of event and amplitude.

Note: This file is created ONLY by the EXDOC_LA library IF the option of discretisation is selected when calculating CCDF.

5.6 Extrapolations

Some of the results have shown that the pretty good behavior of the curves could allow the user to reduce the number of GoldSim [DIRS 169844] calculations and extrapolate some of the results, either on the time of event or on its amplitude. This capability has been thus included in EXDOC.

However, when possible, one should avoid to use this feature, since it may lead to wrong results (if the behavior is not enough good to allow the extrapolation.

5.6.1 Extrapolation on Time of Event

The extrapolation of the time of event may be done in both directions. The code simply shifts the solution from the first (respectively last) time of event available to the extrapolated time of event (considering then that the solution is stationary relatively to the time of event).

Even if it seems reasonable to consider the extrapolation at latter time, it is generally better to save the solution for the last time of event considered.

The extrapolation of earlier time of event has been implemented for reasons of consistency. **However,** current results **do not show** a smooth behavior at early time and it would be dangerous to use this option, at least for the current dose results. It may **eventually** be useful for other data studied, which would show a smoother behavior at early time of event.

A warning message will be written in the log file in case of extrapolation to the left (respectively to the right).

5.6.2 Extrapolation on Amplitude of Event

The extrapolation of the amplitude may be done in both directions. The code will do a linear extrapolation based on the first (or the last as the case may be) amplitude available.

Even if it seems reasonable to consider the extrapolation of small amplitude, it is generally better to save the solution for the first amplitude of event considered.

The extrapolation of bigger amplitude of event has been implemented for reasons of consistency. **However,** current results **do not show** a smooth behavior for biggest amplitude (the behavior is sublinear) and the use of this option will lead to an overestimation of the dose in this case. It may **eventually** be useful for other data studied, which would show a smoother behavior at biggest amplitude of event.

A warning message will be written in the log file in case of extrapolation to the left (respectively to the right). The minimum (respectively maximum) amplitude is not represented and must be extrapolated.

5.7 Limitations of the Code

The value **NB_tevent_saved** must be less than or equal to **NB_tevent**. This value has been created to save some of the time of event considered in the saving of the expected dose on the amplitude. By definition, it must be smaller than NB_tevent. The best coverage will be obtained with NB_tevent_saved taken as a divisor of NB_Tevent

6. MITIGATION MEASURES

Any mitigation measures required will be carried out according to IM-PRO-003, *Software Management*, Section 6.11.

7. TEST PLAN

This documentation outlines the test plan for the EXDOC_LA Version 2.0 software. The software calculates the average expected dose in the Total System Performance Assessment for the License Application (TSPA-LA) model, as well as CCDFs for a given timestep. Both results are summarized with statistics (mean and quantile).

The software being tested by this plan consists of an executable (written in the Delphi language), and a number of DLLs (written in the FORTRAN language). It is a stand-alone software package but requires input data files from GoldSim [DIRS 169844] (a qualified version [i.e., V. 8.02.500 or greater], based on the TSPA-LA model). The detailed testing will be performed with EXDOC_LA.exe on a local PC using simulated data files. An overall check will be performed remotely with TSPA-LA model output files on the TSPA PC cluster.

The simulated data files will be used to provide the testing of EXDOC_LA.exe over a representative range of input while exercising the options available to the user.

The first ten tests are identical to those performed for the verification of EXDOC_LA V1.0.

The new tests cases developed for testing the new functionalities of EXDOC are:

- One test case to verify the Monte Carlo method for estimating CCDF (Test TC-11)
- One test to verify the calculation of expected dose for Seismic GMD (Peak Dose) (Test TC-12)
- One test to verify the calculation of expected dose for Nominal early failure (Test TC-13)
- One test to verify the calculation of expected dose for Igneous Eruptive (Test TC-14)
- One test to verify the calculation of expected dose for Seismic Fault Displacement (FD) (Test TC-15)

- One test to verify the new method for calculating Expected dose for Seismic GMD (10K) (Test TC-16)

- One test to verify the translator function for splitting one GoldSim [DIRS 169844] file into several separated files (Test TC-17.

7.1 Acceptance Criteria

The acceptance criteria for determining the validity of the software are described in Section 7.2. Tables in each section provide acceptance criterion for each step of every test case. Acceptance criteria are based on satisfactory completion of a number of steps for each test and results that match criteria specified for each of the tests. The result of each test case is a pass if the acceptance criteria are met and fail if any of the criteria are not met.

7.2 Test Cases

Instructions for the actual execution of each test shall be provided in the User Information Document for: EXDOC_LA Version 2.0 (Document ID: 11193-UID-2.0-00).

Table 7.2-1 lists the tests to be performed and the requirements satisfied by the particular test. Each test is assigned a specific Test Case Identifier (TC-01 thru TC-17).

All test cases have been developed such that the aleatory and epistemic uncertain parameters have a linear effect on the response to simplify the analytical calculations (as the expected value of one input will lead to the expected value of the output with respect to this input).

Test cases are performed on a local PC under the Windows XP, Windows 2000, and Windows Server 2003 operating systems.

Table 7.2-1. EXDOC_LA Test Cases

Test Number	Test Case	Requirement
TC-01	The first test studies the resulting expected dose from a simple step function. The dose is supposed to be equal to 0 before the event and 1 after the event (no epistemic uncertainty). The frequency of the event is fixed to 10^{-4} / yr. The resulting straight line is going to a 0 dose value at T=0. The range at T=10,000 will be 5.	FR-01, FR-02, FR-03, DR-01, AR-01, AR-02, IR-01, IR-03, IR-04, IR-05, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-02	In the second test, the frequency of the event has been replaced to be distributed uniformly between 2. 10^{-5} / yr and 2. 10^{-4} / yr. The resulting straight lines are all going to a 0 dose value at T=0. The range at T=10,000 will vary from 1 to 10.	FR-03, FR-06.a, FR-06.b, FR-06.c, IR-02, IR-06
TC-03	Test 3 is similar to Test 2 and should give similar results. This time, we have suppressed the earlier and later times of event (i.e., 10 yr and 10,000 yr). This test will check at the validity of the extrapolation on the time of events (knowing that the system is well behaved and gives identical theoretical results). The results are equivalent to the ones for Test 2. The extrapolation on the time of event seems to work properly. The log file indicates that extrapolation has been done for the time of event in both directions.	FR-05, FR-06.d, FR-06.e, FR-06.f

Test Number	Test Case	Requirement
TC-04	Test 4 is similar to Test 1, except that it is applied to the seismic event. For this, 4 times of events have been considered: 100 yr; 1,000 yr; 3,000 yr; and 10,000 yr. Moreover, 4 amplitudes (i.e., surface area damaged for this modeling case) are considered: 1.0, 4.0, 6.0, and 10.0. Because of the uniform distribution applied on the amplitude of event (from 0 to 10), results must be identical to the one obtained for Test 1.	FR-01, FR-02, FR-03, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-05	Test 5 extends Test 4 by treating the value of λ as uniformly distributed from $2x10^{-5}$ to $2x10^{-4}$. The analytical model to which Test 5 results are compared has been defined in Section 5.2.2, so Test 5 results should be identical to those presented in Test 2.	FR-01, FR-02, FR-03, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-06	Test 6 examines the extrapolation in event time using a construct similar to Test 4. Test 6 considers only two times of events: 1,000 yr and 2,000 yr. The code has to extrapolate the dose resulting from events occurring earlier or later than these two times. Results should be concordant with those presented in Test 4. The log file informs the user that no data were available on the minimum and maximum time of event and, thus, must be extrapolated from the available information.	FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-07	Test 7 examines the extrapolation in event amplitude using a construct similar to Test 4. Test 7 considers only two amplitudes: 4.0 and 6.0. The code has to extrapolate the dose resulting from amplitudes greater and less than these two values. Results should identical to those produced in Test 4. The log file contains a warning for the user informing him about the extrapolation in both directions.	FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-08	Test 8 regroups changes made for Test 6 and 7. Now, extrapolations are needed for both time of event (only 1,000 and 2,000 yr available) and amplitude of event (only 4.0 and 6.0 available). Results should be identical to those produced in Test 4. The log file contains warnings for extrapolation of both time of event and amplitude of event in both directions.	FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-09	Test 9 tests the calculation of a CCDF using the discretization technique and discretizing the amplitude variable by quantiles. The input files for Test 9 are the same as for Test 8. Results should be in concordance with those presented in Test 8.	FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-10	Test 10 tests the calculation of a CCDF using the discretization technique and discretizing the amplitude variable by log discretization. The log discretization here should give a better accuracy for low values of the amplitude variable (i.e., those producing dose close to 1), while the accuracy is lowered for high values (those producing dose close to 10). Results should be similar to those presented in Test 8.	IR-03, IR-05, IR-06, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07

Test Number	Test Case	Requirement
TC-11	Test 11 uses the same input as Test 1, but the CCDF is calculated using the Monte Carlo technique. Results should be identical to theoretical results based on the probability of having 2 or more events.	FR-04, FR-06.a, FR-06.b, FR-06.d, FR-06.e, FR-06.f, DR-02, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07
TC-12	TC-12 tests the Monte Carlo approach used for the Seismic GMD (peak dose) scenario. Results for expected dose (file _regul.txt) should be 4, increasing the second order polynomials, whose maximum is obtained at 100 yr, and equal, respectively, to 0.5, 1., 2., and 4. CCDF at 100 yr should give 4 straight lines, starting from X=0, Y=1 and reaching Y=0 for, respectively, X=1, 2, 4, and 8.	FR_MC-01, FR_MC-02, FR_MC-03, FR_MC-04, FR_MC-05.a, FR_MC-05.b, FR_MC-05.c, FR_MC-05.d
TC-13	TC-13 tests the convolution method, implemented in EXDOC_LA_CV and used for Nominal early failure scenario. Results of expected value should be 4 straights lines, whose values at 10,000 yr are respectively 11.7, 28.8, 59.4 and 122.4.	FR_CV-01, FR_CV-02, FR_CV-03, FR_CV-04, FR_CV-05.a, FR_CV-05.b, FR_CV-05.c, FR_CV-05.d, FR_CV-05.e, IR-07, IR-08, IR-09
TC-14	TC-14 tests the mix Monte Carlo/integration over time of event, which is necessary for the igneous eruptive scenario. Result of expected value should be 4 straights lines, whose values at 10,000 yr are, respectively, 3.7, 7.4, 18.5, and 29.6.	FR_MCT-01, FR_MCT-02, FR_MCT-03, FR_MCT-04, FR_MCT-05.a, FR_MCT-05.b, FR_MCT-05.c, FR_MCT-05.d
TC-15	TC-15 tests the convolution method implemented in EXDOC_LA_FD and used for seismic FD. Results of expected value should be 4 straights lines, whose values at 10,000 yr are, respectively, 11.7, 28.8, 59.4, and 122.4. This test is the same as TC-13 but is applied to a different part of the EXDOC code.	FR_FD-01, FR_FD-02, FR_FD-03, FR_FD-04, FR_FD-05.a, FR_FD-05.b, FR_FD-05.c, FR_FD-05.d, IR-03, IR-04, IR-07, IR-08, IR-09, IR-10
TC-16	TC-16 specifically tests the library EXDOC_LA_SE. This library uses the Monte Carlo approach to determine the expected value for the seismic GMD modeling case at 10,000 yr. The library calculates the expected value at each timestep and estimates the CCDF using the Monte Carlo approach.	FR_SE-01, FR_SE-02, FR_SE-03, FR_SE-04, FR_SE-05.a, FR_SE-05.b, FR_SE-05.c, FR_SE-05.d
TC-17	TC-17 specifically tests the library EXDOC_LA_TR. This library separates the information contained in a single GoldSim [DIRS 169844] output file into several input files that are formatted for EXDOC.	FR_TR-01, FR_TR-02.a, FR_TR-02.b, OR-08

The Test Case Log (Section 7.3) will be used to document the results of Test Cases TC-01 through TC-17.

7.2.1 Test Case TC-01

The first test studies the resulting expected dose from a simple step function.

The dose is supposed to be equal to 0 before the event and 1 after the event (no epistemic uncertainty). The frequency of the event is fixed to 10^{-4} / yr.

The expected amplitude of event (number of WPs destroyed) is fixed to 5.

10 files of pseudo doses have been generated for the following time of events:

10 yr; 100 yr; 200 yr; 600 yr; 1,000 yr; 2,000 yr; 3,000 yr; 5,000 yr; 7,000 yr; and 10,000 yr.

The dose is considered to be calculated for an amplitude (number of WPs destroyed) equal to 1.

The expected dose at a time t is easy to calculate. We have:

$$E(D)_t = \sum_{i=0}^{\infty} P(nb\_event = i)_t . D(nb\_event = i)_t \qquad \text{(Equation 7)}$$

Where *nb_event* represents the number of events considered.

In our case, the probability for having a given number of events is easy to estimate since we know it follows a Poisson law; moreover, the dose obtained for *i* events is exactly equal to 5*i* (since we consider the expected amplitude equal to 5).

Thus, Equation 7 is equal to:

$$\begin{aligned} E(D)_t &= \sum_{i=0}^{\infty} e^{-\lambda t} \frac{(\lambda t)^i}{i!} * 5i \\ &= 5e^{-\lambda t} \sum_{i=1}^{\infty} \frac{(\lambda t)^i}{(i-1)!} \\ &= 5(\lambda t) e^{-\lambda t} \sum_{i=0}^{\infty} \frac{(\lambda t)^i}{i!} \\ &= 5(\lambda t) \end{aligned} \qquad \text{(Equation 8)}$$

where the last row comes from the equality: $\sum_{i=0}^{\infty} \frac{x^i}{i!} = e^x$.

So, the expected value is simply a linear function on t. Since lambda has been taken as a constant value of 10^{-4} / yr, the formula for the expected dose is:

$$E(D)_t = \frac{5t}{10^4} \qquad \text{(Equation 9)}$$

So, the solution of the expected dose should be a straight line equal to 0 at t=0 and ($5\frac{10^4}{10^4} = 5$) 5 at t=10,000 yr.

The result of the code, presented in Figure 11 (left), is concordant with the analytical solution. A zoom on the right of Figure 11 shows the accuracy of the discretization (every 10 yr).

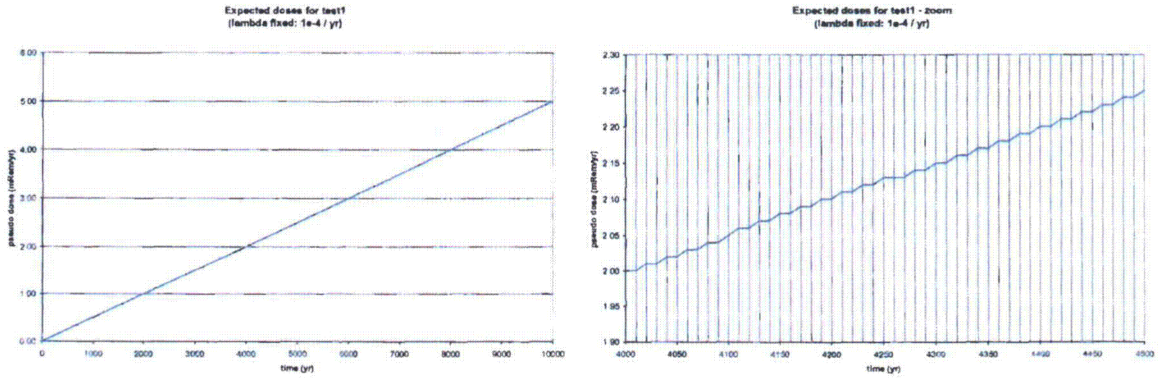


Figure 11. Result of Expected Dose for Test 1 (Left) with Zoom between 4,000 and 4,500 yr (Right)

The statistics calculated on the expected doses give, of course, the same straight line and are not presented here.

The probability law on the amplitude of the event is a uniform law from 1 to 10 (which increases the factor from 1 to 10). Since the time of event is defined by a Poisson law, it is distributed uniformly. The resulting CCDF is also a straight line with a probability of $\left(1-\frac{1}{e}\right) \approx 0.63$ for a dose equal to 0 (it represents the probability of having at least one event occurring) and a probability of 0 for a dose equal to 10. The result obtained in the code (here, the average of CCDF, but each CCDF was identical since there is no epistemic uncertainty) is very close to the theoretical result (Figure 12). Since the discretization on the amplitude begins at a value of 1.0, the code has a slightly higher value at this exact point, which is corrected.

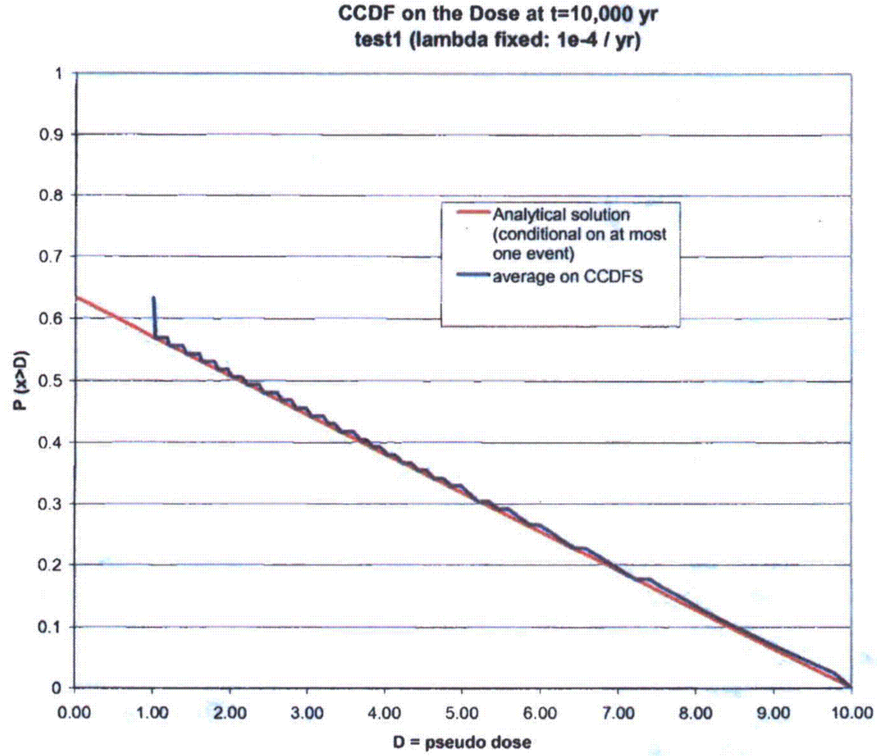


Figure 12. Comparison of Theoretical CCDF with Result from the Code at 10,000 yr for Test 1

A mapping of the results of the discretization has been plotted for T=5,000 yr (Figure 13). It shows that the dose is a step function according to the time of event. Since the time of interest here is 5,000 yr, every dose calculated for a later time of event is equal to 0. The dose is linearly dependent on the amplitude of event.

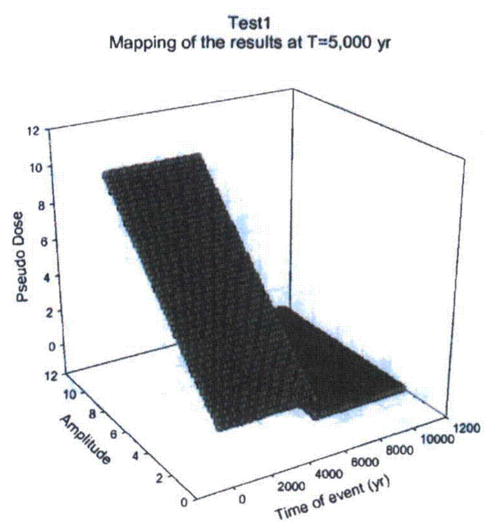


Figure 13. Mapping of the Results for Test 1 at 5,000 yr

Table 7.2-2 gives the steps to be performed for Test Case TC-01 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-01, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-2. EXDOC_LA Test Case TC-01

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, DR-01, AR-01, AR-02, IR-01, IR-03, IR-04, IR-05, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07.		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-01.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-01.2	Load the following simplified input files locally from TC-01\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-01.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-01.4	Create the information files using the GUI in accordance to specificities of Test TC-01.	A green color indicates the status of the files in the GUI.
TC-01.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-01\output.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization at a given time, so this technical requirement is met.

7.2.2 Test Case TC-02

In the following test, the frequency of the event has been replaced to be distributed uniformly between 2 x 10^{-5} / yr and 2 x 10^{-4} / yr. Equation 8 is still valid, which means that the expected values are straight lines defined by the equation:

$$E(D)_t = 5\lambda t \qquad \text{(Equation 10)}$$

The straights lines are all going to a 0 dose value at T=0. The range at T=10,000 will vary from 1 to 10. The resulting doses at 10,000 yr should look uniformly distributed. Results from the code, presented in Figure 14, are concordant with the analytical solution.

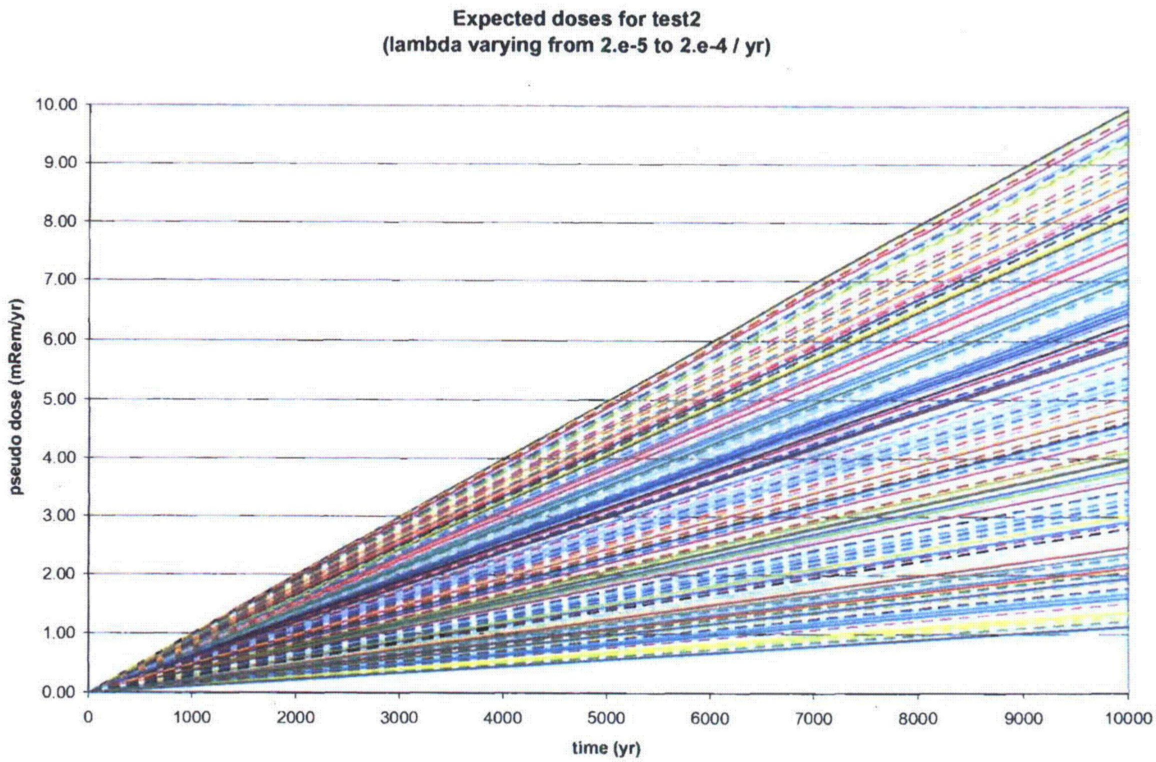


Figure 14. Results from Test Case 2

This test is a means of checking the correctness of the statistical calculations. We know indeed that the solutions are straights lines, equal to values ranging from 1 to 10 at 10,000 yr. It is easy to calculate the average of these lines, as well as the quantiles. Since the values are uniformly distributed between 1 and 10 (a range of 9), one expects to have the median and average identical (symmetric distribution) curves from 0 at t=0 to $(\frac{10+1}{2})$ 5. 5 at t=10,000 yr.

The 5th and 95th percentiles should also be straight lines from 0 at t=0 to 1.45 and 9.55 at t=10,000 yr., respectively.

Results presented in Figure 14 seem concordant with these assumptions.

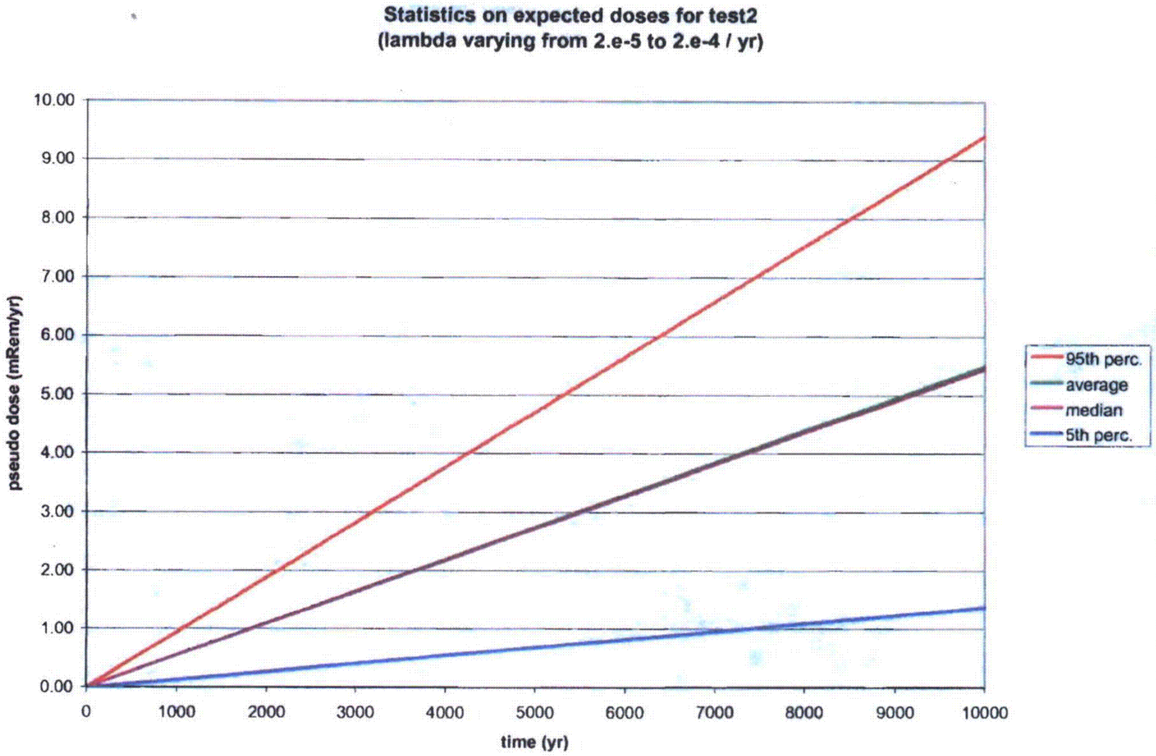


Figure 15. Statistics on Expected Dose for Test 2

The statistics on CCDF are simple to calculate analytically. As for Test 1, the average on CCDF is a straight line from 0.63 (for a dose equal to 0) to 0 (for a dose equal to 10).

The quantile on CCDF will also give straights line with a probability of 0 for a dose equal to 10. The only thing to determine is the probability to have a dose higher than 0, which is the probability of having at least one event. For the 5th percentile, median, and 95th percentile, the values of lambda are 2.9×10^{-5}, 1.1×10^{-4}, and 1.91×10^{-4}, respectively, which lead to a probability of 25%, 67%, and 85% of having one or more events.

In Figure 15, the theoretical straight lines have been superposed to the calculated statistics on CCDF. The good match indicates that the calculations are done correctly.

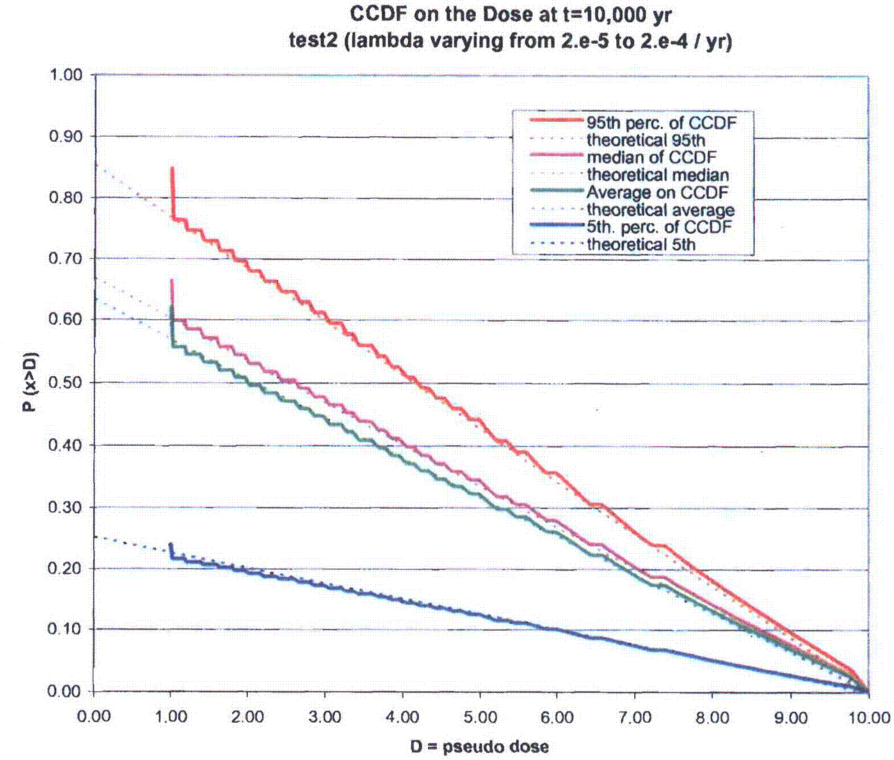


Figure 16. Statistics on CCDF for Test 2

Table 7.2-3 gives the steps to be performed for Test Case TC-02 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-02, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-3. EXDOC_LA Test Case TC-02

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-03, FR-06.a, FR-06.b, FR-06.c, IR-02, IR-06		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-02.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-02.2	Load the following simplified input files locally from TC-02\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-02.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-02.4	Create the information files using the GUI in accordance to specificities of Test Case TC-02.	A green color indicates the status of the files in the GUI.
TC-02.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-02\output.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error and verifying file content in notepad, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp.txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d.txt") without error, this requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

7.2.3 Test Case TC-03

Test 3 is similar as Test 2 and should give similar results. This time, we have suppressed the earlier and later times of event (i.e., 10 yr and 10,000 yr). This test will check at the validity of the extrapolation on the time of events (knowing that the system is well behaved and gives identical theoretical results).

The three following pictures (Figure 17, Figure 18, and Figure 19) are equivalent to the ones presented in the previous section. The extrapolation on the time of event seems to work properly.

The log file indicates that extrapolation has been done for the time of event in both directions.

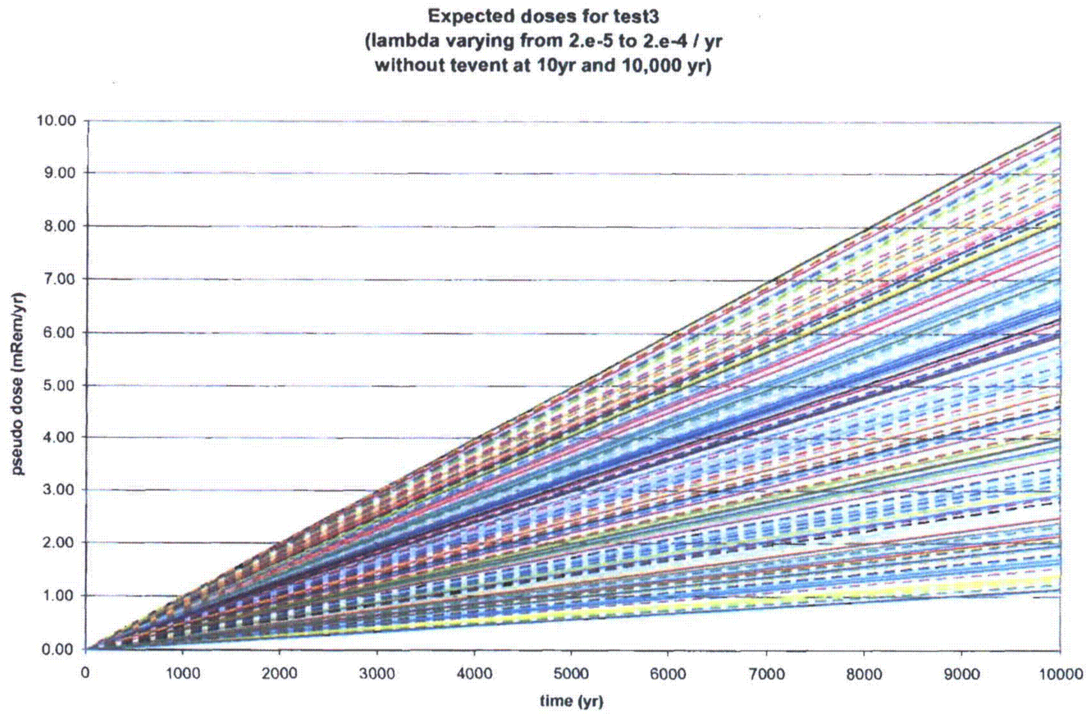


Figure 17. Result of Expected Dose (with Extrapolation) for Test 3

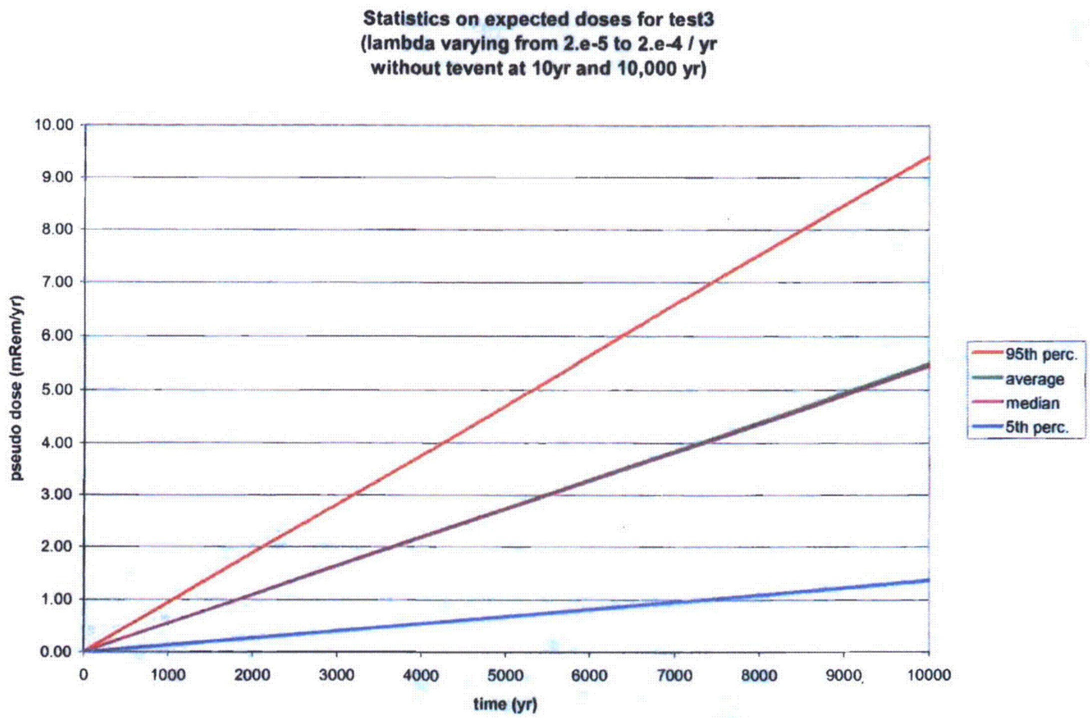


Figure 18. Statistics on Expected Dose (with Extrapolation) for Test 3

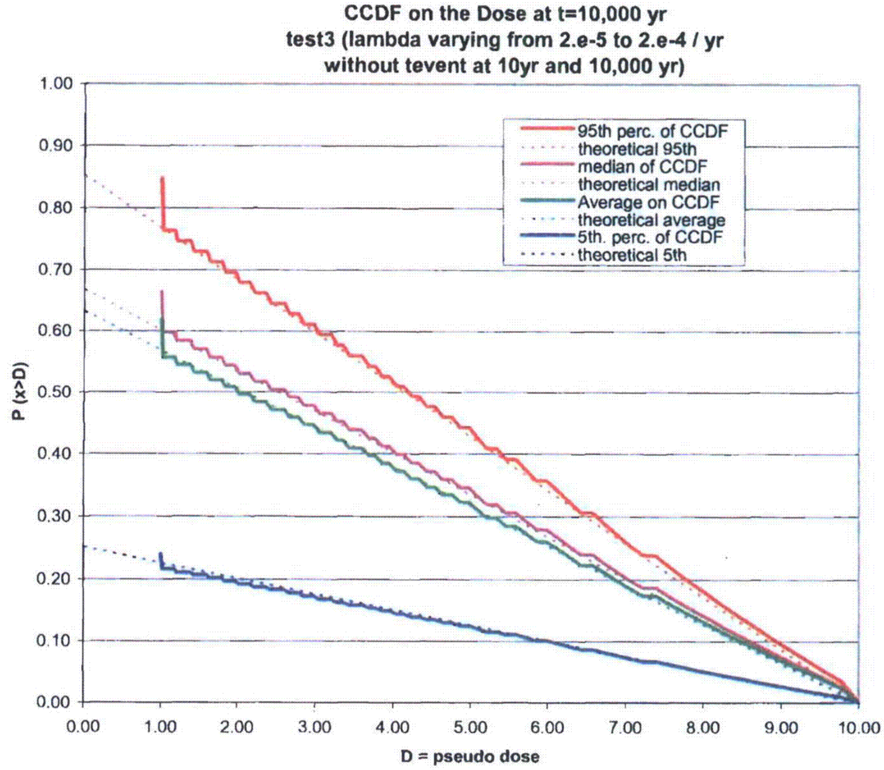


Figure 19. Statistics on CCDF (with Extrapolation) for Test 3

Table 7.2-4 gives the steps to be performed for Test Case TC-03 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-03, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-4. EXDOC_LA Test Case TC-03

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-05, FR-06.d, FR-06.e, FR-06.f		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-03.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-03.2	Load the following simplified input files locally from TC-03\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-03.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-03.4	Create the information files using the GUI in accordance to specificities of Test TC-03.	A green color indicates the status of the files in the GUI.
TC-03.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-031\output.

FR-05 By demonstrating the expected extrapolation behavior, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map.txt") without error, this requirement is met.

7.2.4 Test Case TC-04

Test 4 is similar to Test 1 except that it is applied to the seismic event. Four times of events have been considered: 100 yr; 1,000 yr; 3,000 yr; and 10,000 yr. Moreover, 4 amplitudes (i.e., surface area damaged for this modeling case) are considered: 1.0, 4.0, 6.0, and 10.0.

Because of the uniform distribution applied on the amplitude of event (from 0 to 10), results must be identical to the one obtained for test 1 (Section 5.2.1).

Results shown in Figure 20 and Figure 21 demonstrate good concordance with these results.

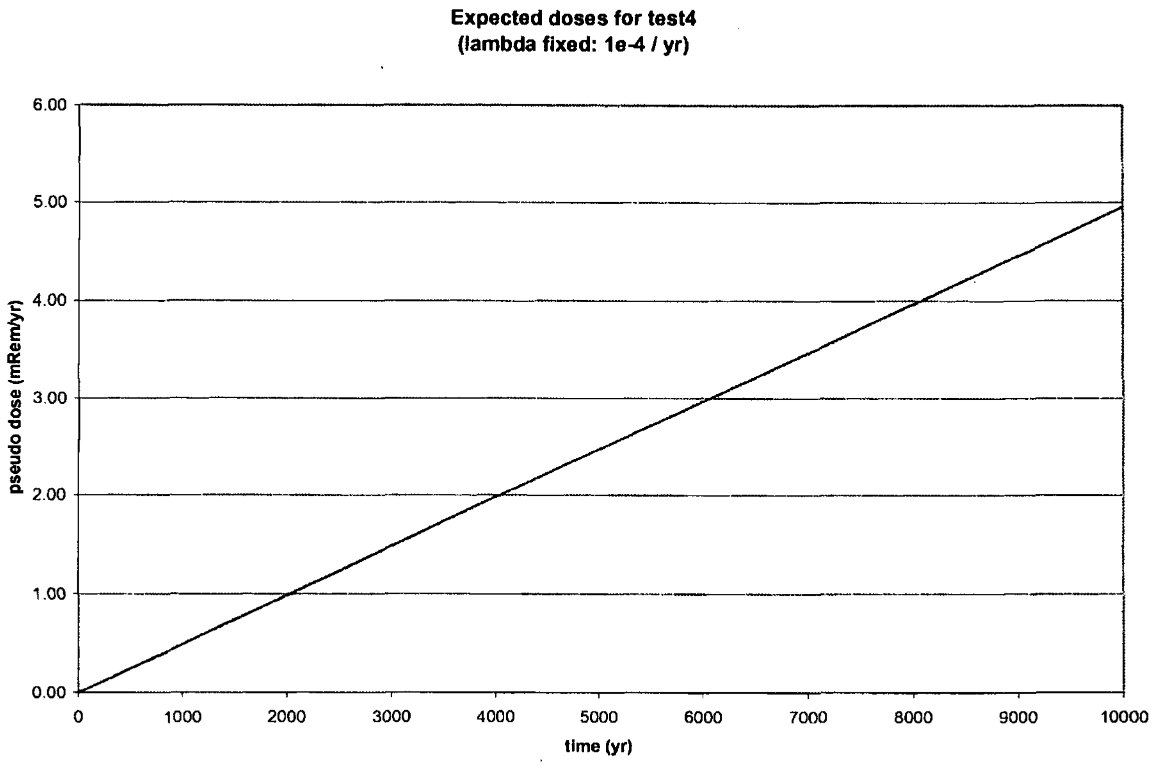


Figure 20. Result of Expected Dose for Test 4

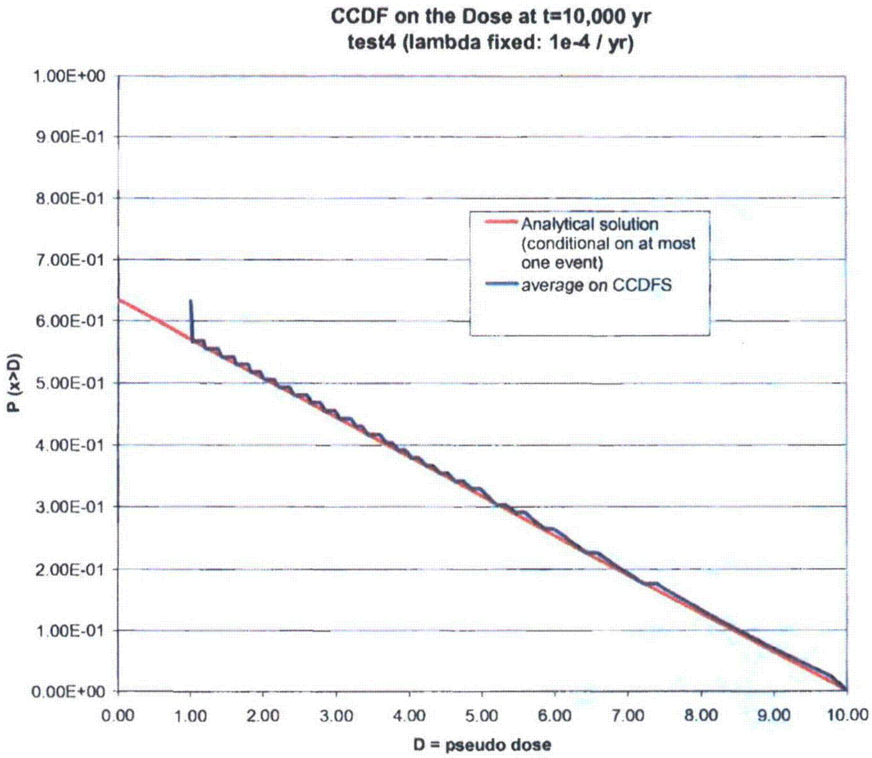


Figure 21. Comparison of Theoretical CCDF with the One Obtained with the Code at 10,000 yr for Test 4

Table 7.2-5 gives the steps to be performed for Test Case TC-04 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-04, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-5. EXDOC_LA Test Case TC-04

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07.		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-04.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-04.2	Load the following simplified input files locally from TC-04\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-04.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-04.4	Create the information files using the GUI in accordance to specificities of Test TC-04.	A green color indicates the status of the files in the GUI.
TC-04.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-04\output.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp. txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat. txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d. txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map. Txt") without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.5 Test Case TC-05

Test 5 is identical to Test 4 except that the value of lambda is uniformly distributed from $2x10^{-5}$ to $2x10^{-4}$. The analytical model has been defined in Section 5.2.2 and results must be identical to those presented in this section.

Results presented in Figure 22, Figure 23, and Figure 24 are identical to those presented in Section 5.2.2.

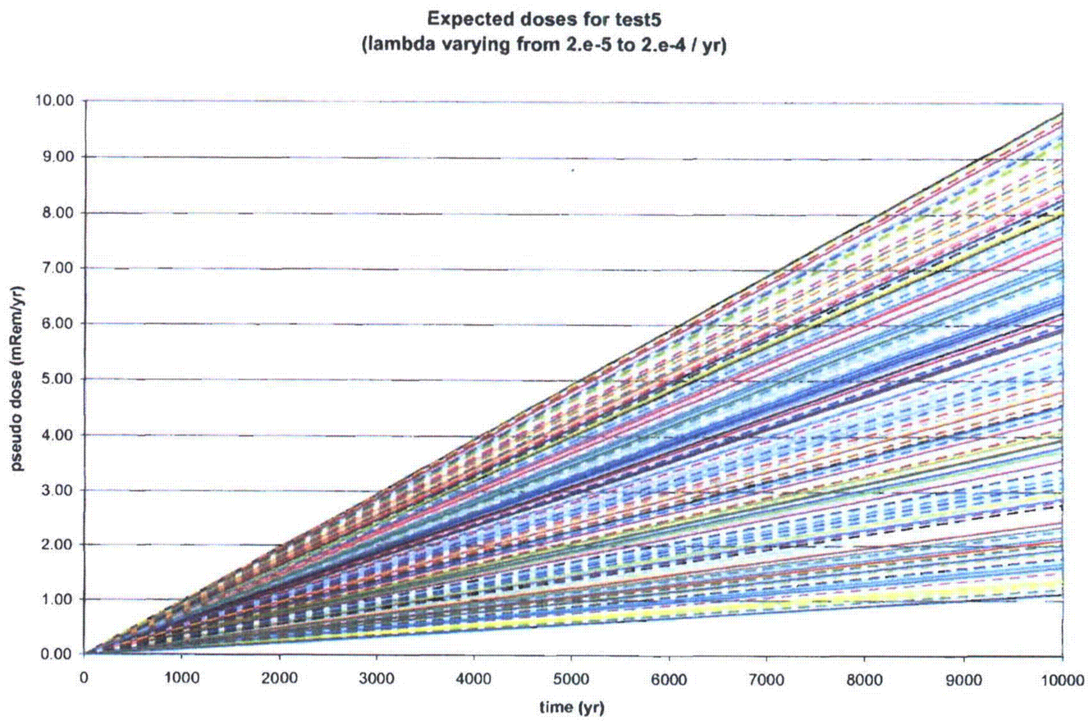


Figure 22. Distribution of Expected Dose for Test 5

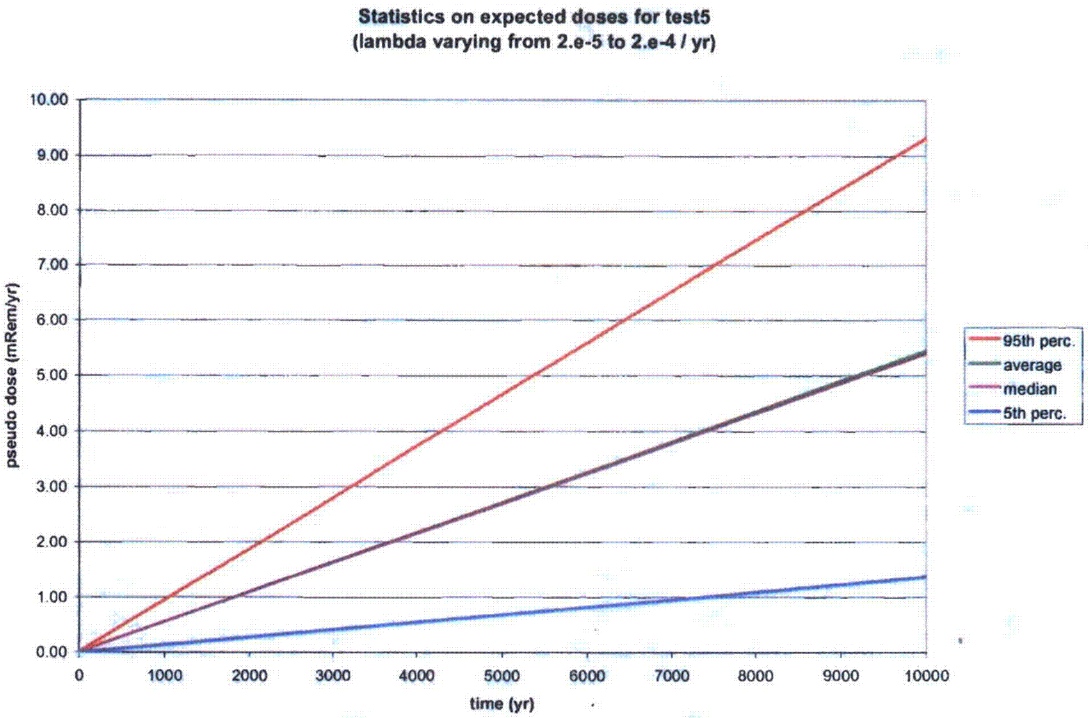


Figure 23. Statistics on Expected Dose for Test 5

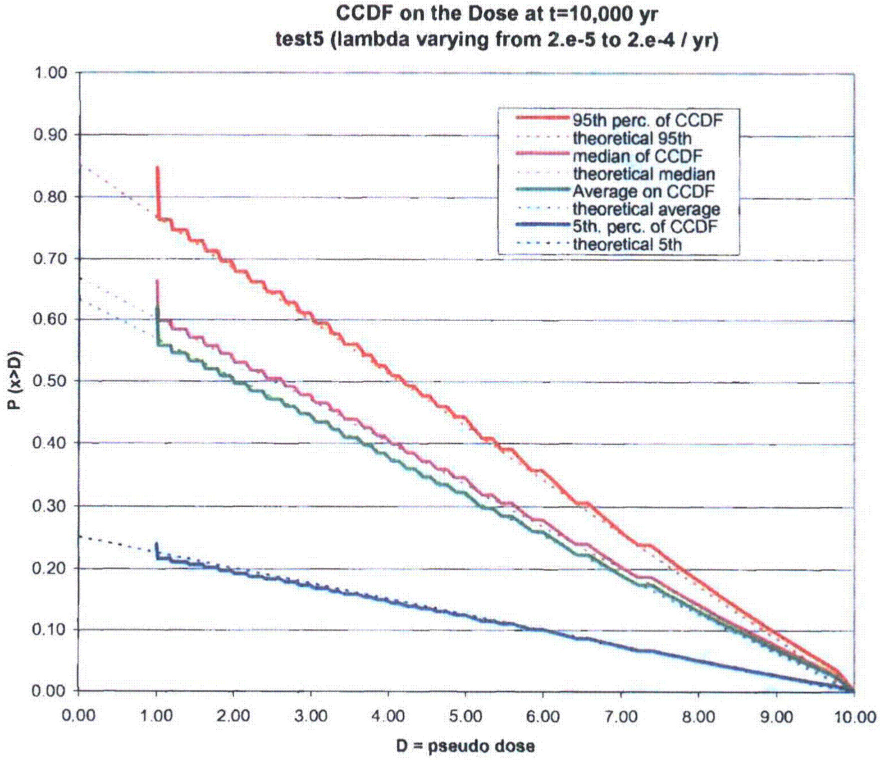


Figure 24 Statistics on CCDF (at 10,000 yr) for Test 5

Table 7.2-6 gives the steps to be performed for Test Case TC-05 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-05, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-6. EXDOC_LA Test Case TC-05

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07.		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-05.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-05.2	Load the following simplified input files locally from TC-05\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-05.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-05.4	Create the information files using the GUI in accordance to specificities of Test TC-05.	A green color indicates the status of the files in the GUI.
TC-05.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-05\output.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp. txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat. txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d. txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map. Txt") without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.6 Test Case TC-06

Test 6 is identical to Test 5 and should conduct to similar results. Here, only two times of events (1,000 yr and 2,000 yr) are considered. The code has to extrapolate the time of event in both directions.

Results in Figure 25, Figure 26, and Figure 27 are concordant with those presented in the previous section. The log file informs the user that no data was available on the minimum and maximum time of event and, thus, must be extrapolated from the available information.

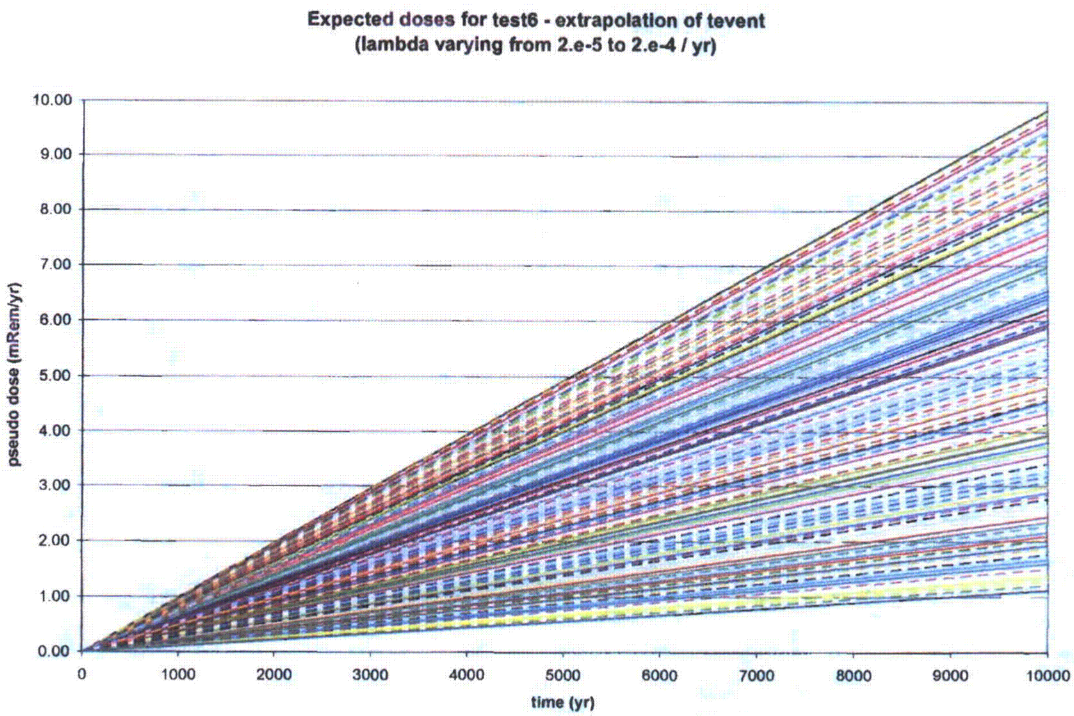


Figure 25. Expected Doses for Test 6 (Extrapolation on Tevent)

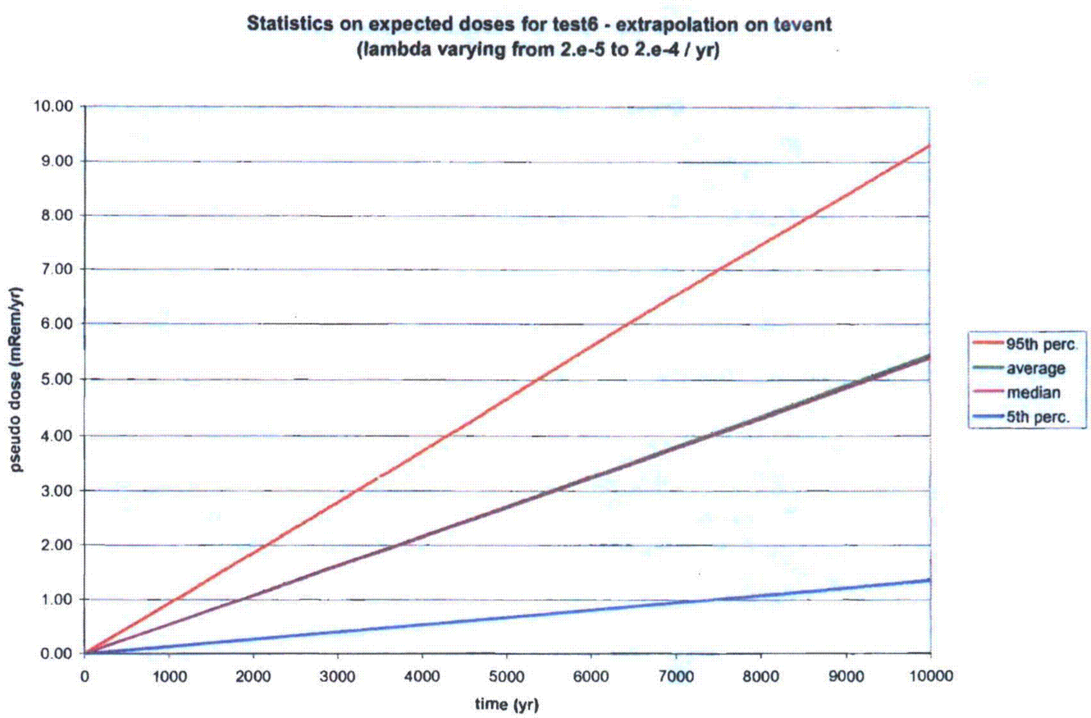


Figure 26. Statistics on Expected Dose for Test 6 (Extrapolation on Time of Event)

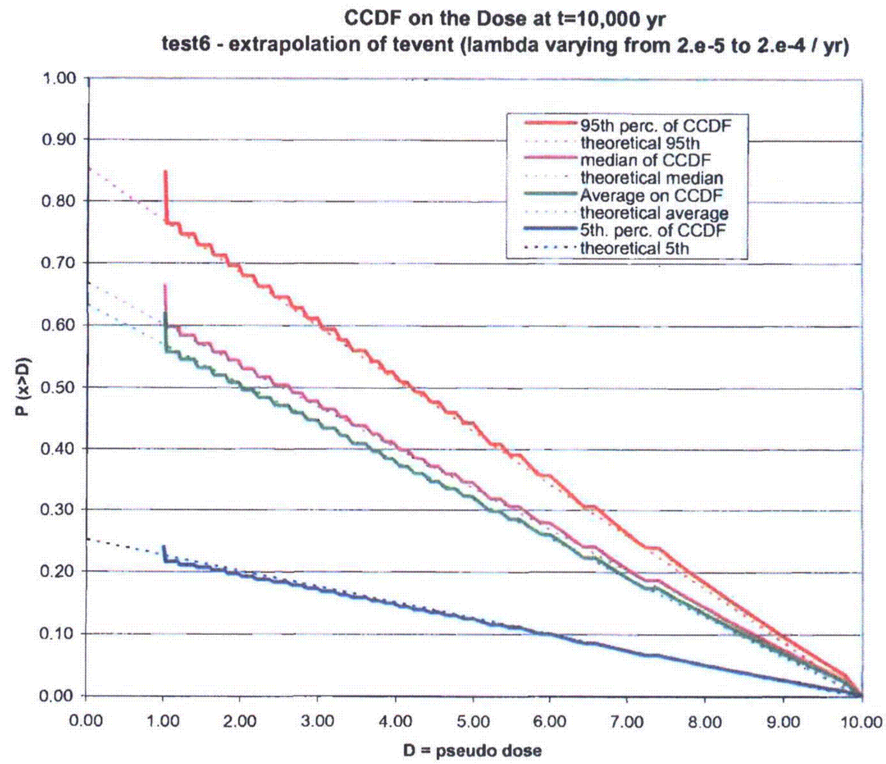


Figure 27. Statistics on CCDF at T=10,000 yr for Test 6 (Extrapolation on Time of Event)

Table 7.2-7 gives the steps to be performed for Test Case TC-06 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-06, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-7. EXDOC_LA Test Case TC-06

Test Step	Description of Step	Step Acceptance Criteria
Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
TC-06.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-06.2	Load the following simplified input files locally from TC-06\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-06.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-06.4	Create the information files using the GUI in accordance to specificities of Test TC-06.	A green color indicates the status of the files in the GUI.
TC-06.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media *TC-06\output*.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

FR-05 By satisfactorily *performing the desired calculations using data from an abbreviated input* file, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp. txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat. txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d. txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map. Txt") without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.7 Test Case TC-07

Test 7 has no equivalent in the igneous intrusive modeling case. It is identical to Test 5 and should conduct to similar results. Here, only two amplitudes of event (4.0 and 6.0) are considered. The code has to extrapolate the amplitude of event in both directions. Figure 28, Figure 29, and Figure 30 show results identical to those shown in the previous section.

The log file contains a warning for the user, informing him about the extrapolation in both directions.

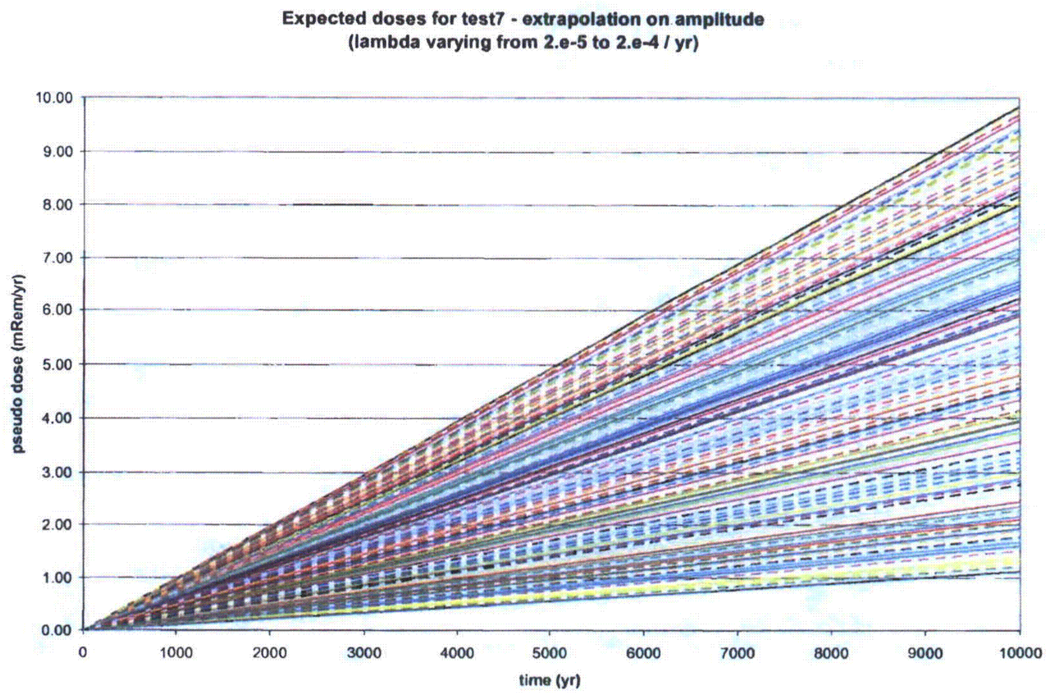


Figure 28. Expected Doses for Test 7 (Extrapolation on Amplitude)

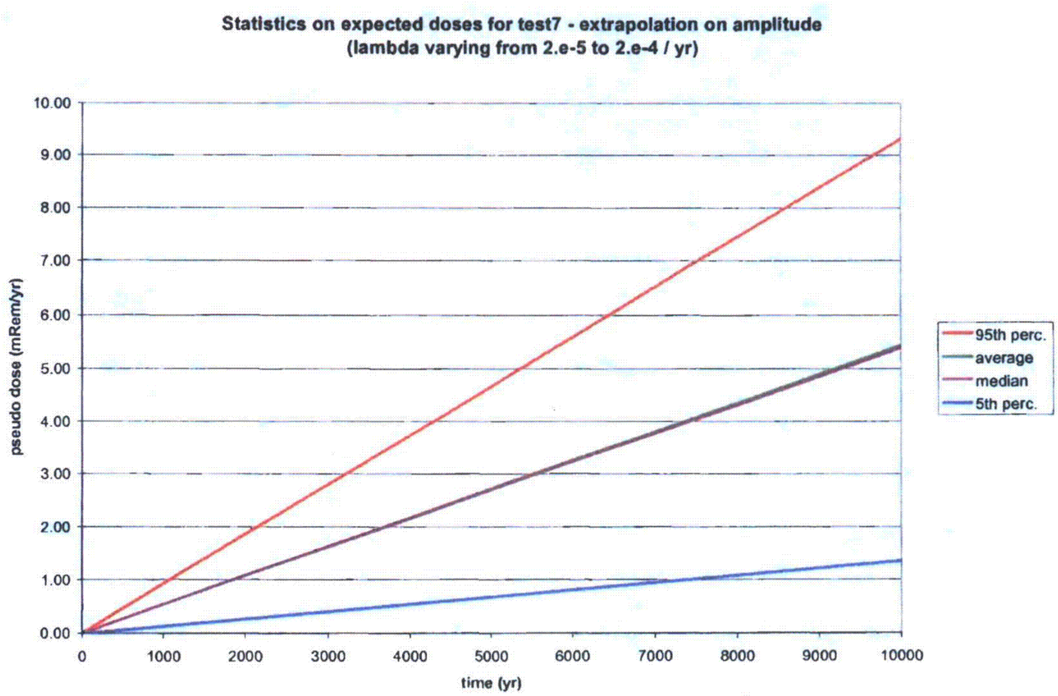


Figure 29. Statistics on Expected Doses for Test 7 (Extrapolation on Amplitude)

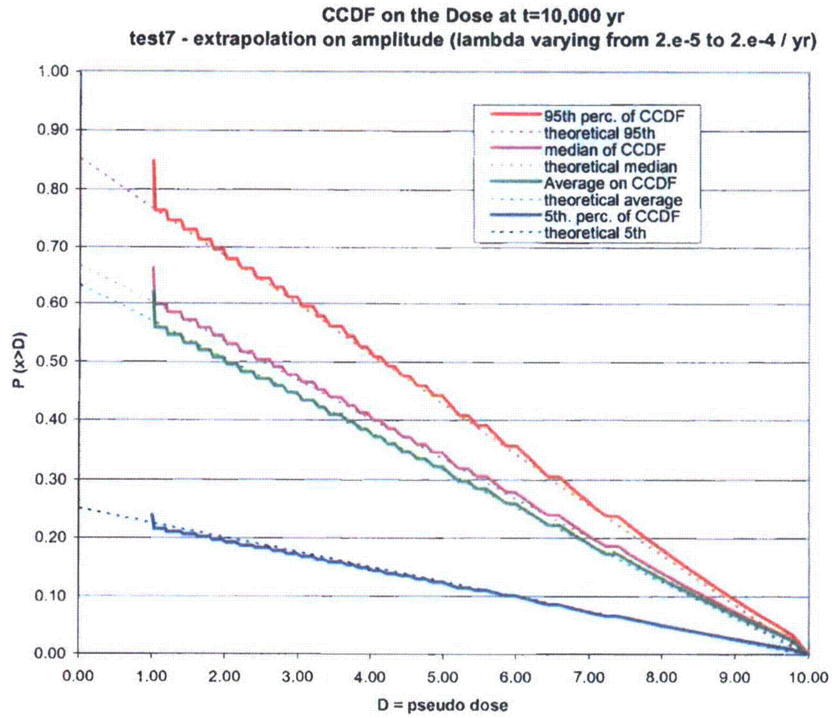


Figure 30. Statistics on CCDF for Test 7 (Extrapolation on Amplitude)

Table 7.2-8 gives the steps to be performed for Test Case TC-07 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-07, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-8. EXDOC_LA Test Case TC-07

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-07.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-07.2	Load the following simplified input files locally from TC-07\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-07.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-07.4	Create the information files using the GUI in accordance to specificities of Test TC-07.	A green color indicates the status of the files in the GUI.
TC-07.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-07\output.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

FR-05 By satisfactorily performing the desired calculations using data from an abbreviated input file, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp. txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat. txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d. txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map. Txt") without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.8 Test Case TC-08

Test 8 regroups changes made for Tests 6 and 7. Now, extrapolations are needed for both times of events (only 1,000 yr and 2,000 yr available) and amplitudes of event (only 4.0 and 6.0 available). Results (Figure 31, Figure 32, and Figure 33) are identical to the ones in the previous sections.

The log file contains warnings for extrapolation of both time of event and amplitude of event in both directions.

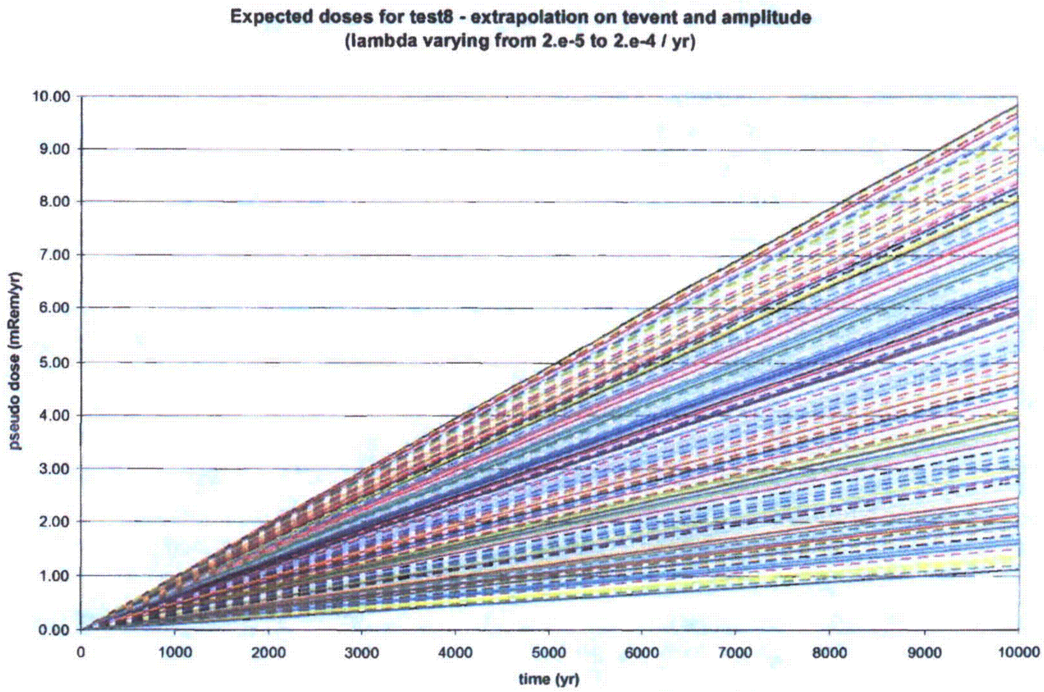


Figure 31. Expected Doses for Test 8 (Extrapolation for Both Time and Amplitude of Event)

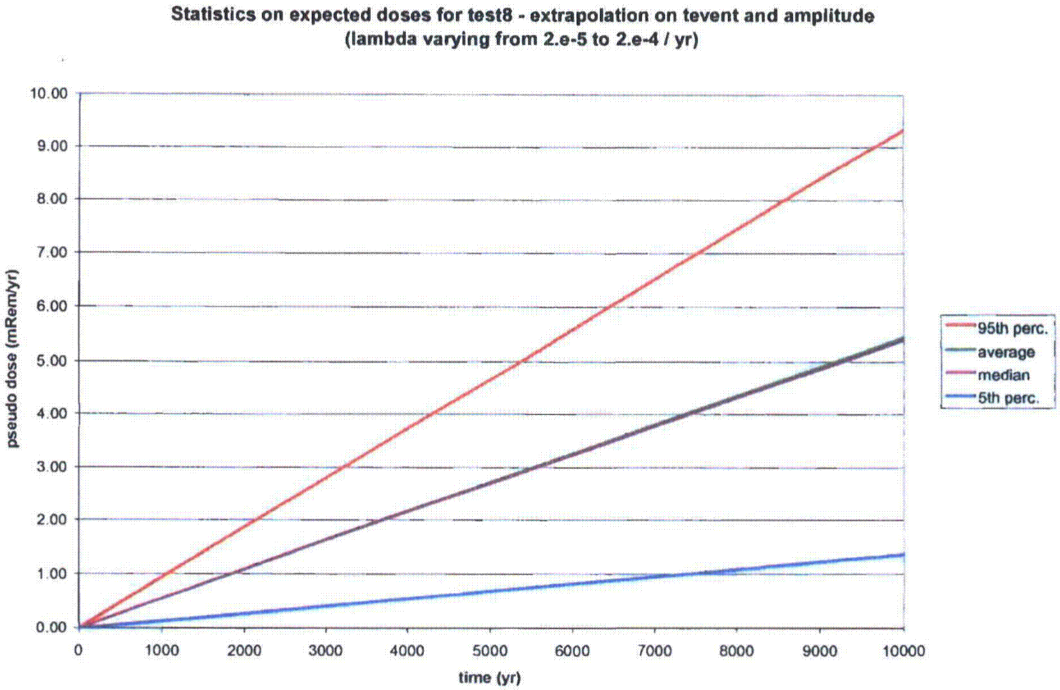


Figure 32. Statistics on Expected Doses for Test 8 (Extrapolation on Both Time and Amplitude of Event)

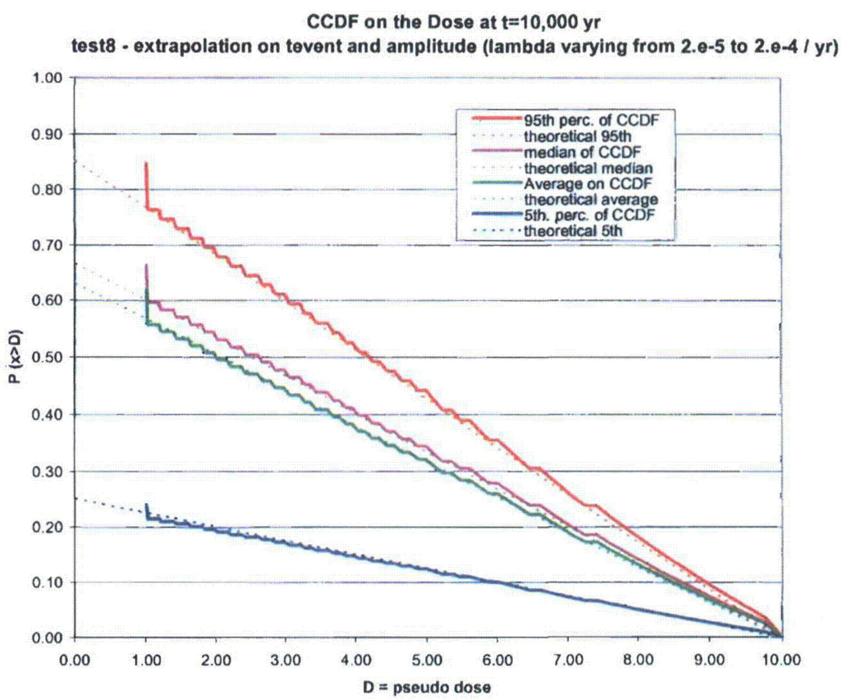


Figure 33. Statistics on CCDF for Test 8 (Extrapolation on Both Time and Amplitude of Event)

Table 7.2-9 gives the steps to be performed for Test Case TC-08 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-08, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-9. EXDOC_LA Test Case TC-08

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07.		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-08.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-08.2	Load the following simplified input files locally from TC-08\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-08.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-08.4	Create the information files using the GUI in accordance to specificities of Test TC-08.	A green color indicates the status of the files in the GUI.
TC-08.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-08\output.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

FR-05 By satisfactorily performing the desired calculations using data from an abbreviated input file, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp. txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat. txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d. txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map. Txt") without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.9 Test Case TC-09

Test Case 9 tests the calculation of the CCDF using the discretization technique. The discretization technique on the amplitude of event for calculating CCDF is the same for the igneous intrusive and seismic modeling cases; the technique is tested using input files for the seismic modeling case. Since the discretization concerns only the CCDF, only the CCDF part of the code is run and only the statistics on CCDF are compared.

Test 9 uses the same input files as Test 8. The discretization of the amplitude variable is based on quantiles. Results below (Figure 34) show concordance with those presented on Figure 33 and that the linear discretization seems to work properly.

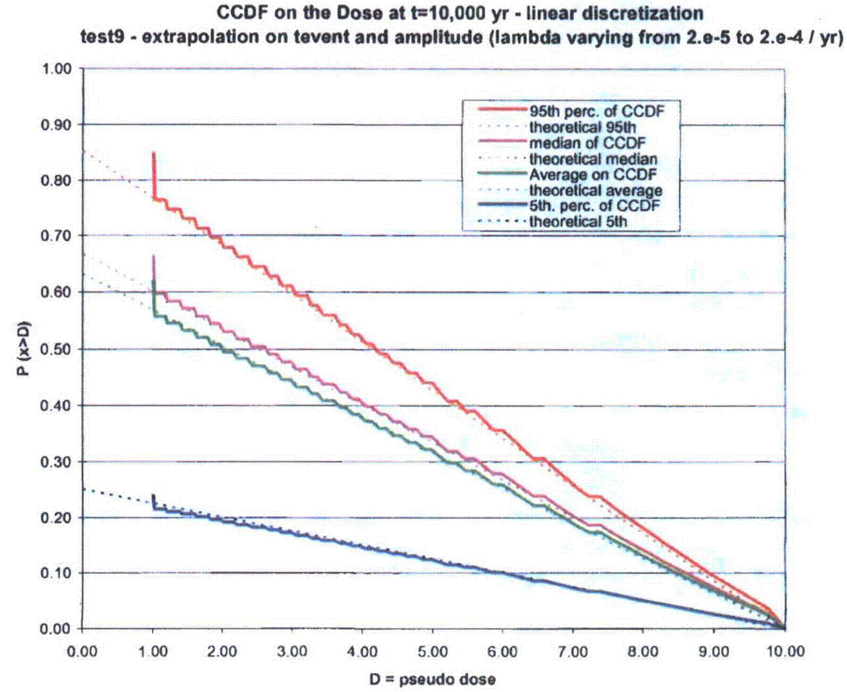


Figure 34. Statistics on CCDF for Test 9 (Linear Discretization on Dose)

Table 7.2-10 gives the steps to be performed for Test Case TC-09 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-09, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-10. EXDOC_LA Test Case TC-09

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-01, FR-02, FR-03, FR-05, FR-06.a, FR-06.b, FR-06.c, FR-06.d, FR-06.e, FR-06.f, DR-01, AR-01, AR-02, IR-01, IR-02, IR-03, IR-04, IR-05, IR-06, OR-01, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-09.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-09.2	Load the following simplified input files locally from TC-09\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-09.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-09.4	Create the information files using the GUI in accordance to specificities of Test TC-09.	A green color indicates the status of the files in the GUI.
TC-09.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-09\output.

FR-01 By satisfactorily creating the input control file (info.dat) without error, this requirement is met.

FR-02 By satisfactorily creating the input parameter file (expc.dat) without error, this requirement is met.

FR-03 By satisfactorily creating the input parameter file (ccdf.dat) without error, this requirement is met.

FR-05 By satisfactorily performing the desired calculations using data from an abbreviated input file, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp. txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat. txt") without error, this requirement is met.

FR-06.c By satisfactorily calculating and outputting the doses for a given LHS realization file ("_d. txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf. Txt") without error, this requirement is met.

FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map. Txt") without error, this requirement is met.

DR-01 The EXDOC_LA program is executed as a standalone EXE with associated DLLs, so this technical requirement is met.

AR-01 The EXDOC_LA program was developed under the Windows XP operating system, so this technical requirement is met.

AR-02 The operation of the EXDOC_LA program on a Windows XP system without a system error meets this requirement.

IR-01 The EXDOC_LA program reads an ASCII text formatted dose file that contains the dose data calculated by GoldSim, so this technical requirement is met.

IR-02 The EXDOC_LA program reads an ASCII text formatted lambda file that contains the values sampled of the disruptive event frequency, so this technical requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-01 The EXDOC_LA program writes a log file giving information about the execution, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.10 Test Case TC-10

The test looks at the log discretization on the amplitude for calculating a CCDF. The log discretization here should give a better accuracy for low doses (i.e., close to 1) while the accuracy is lowered for high doses (close to 10).

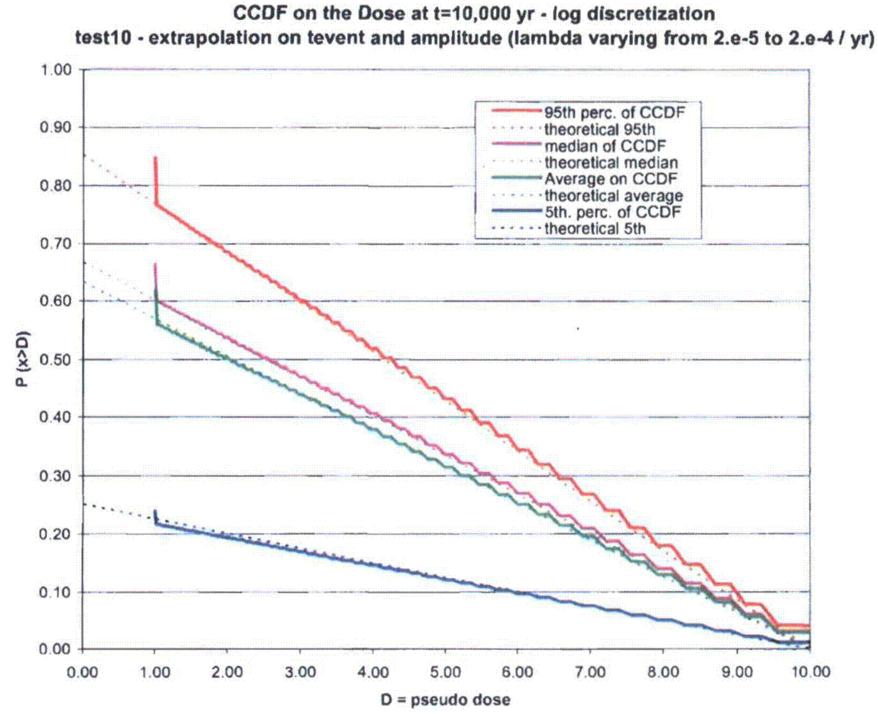


Figure 35. Statistics on CCDF for Test 10 (Log Discretization)

Table 7.2-11 gives the steps to be performed for Test Case TC-10 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-10, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-11. EXDOC_LA Test Case TC-10

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: IR-03, IR-05, IR-06, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-10.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-10.2	Load the following simplified input files locally from TC-10\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-10.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-10.4	Create the information files using the GUI in accordance to specificities of Test TC-10.	A green color indicates the status of the files in the GUI.
TC-10.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-10\output.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-05 The EXDOC_LA program reads an ASCII text formatted quantile file that contains the list of quantile, so this technical requirement is met.

IR-06 The EXDOC_LA program reads an ASCII text formatted amplitude law file that contains the CDF associated with the probability on the amplitude, so this technical requirement is met.

OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.

OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.

OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.

OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.

OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.

OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met..

7.2.11 Test Case TC-11

Test Case TC-11 uses the same model as Test Case TC-01. This test is used only to compare the Monte Carlo approach for estimating a CCDF versus the discretization approach (used in TC-01). The calculation of expected dose is identical and is not considered in this test.

The dose is supposed to be equal to 0 before the event and 1 after the event (no epistemic uncertainty). The frequency of the event is fixed to 10^{-4} / yr.

The expected amplitude of event (number of WPs destroyed) is fixed to 5.

Ten files of pseudo doses have been generated for the following time of events:

10 yr; 100 yr; 200 yr; 600 yr; 1,000 yr; 2,000 yr; 3,000 yr; 5,000 yr; 7,000 yr; and 10,000 yr.

The dose is considered to be calculated for an amplitude (number of WPs destroyed) equal to 1.

In TC-01, the resulting theoretical CCDF, which is conditional on exactly one event, was a straight line with a probability of $\left(1-\frac{1}{e}\right) \approx 0.63$ for a dose equal to 0 (it represents the probability of having at least one event occurring) and a probability of 0 for a dose equal to 10.

By using the Monte Carlo method, multiple events are included in the CCDF.

The first step to derivate the theoretical CCDF is to calculate the probability of multiple events. The events follow a Poisson process with the expected number of events given the time period [0, 10,000 yr] equal to 1 (it is equal to $x=\lambda T$ with $\lambda=10^{-4}$ and $T=10^{4}$). The probabilities of having 0 to 4 events are given below:

$$P(x=0) = e^{-1} \approx 0.37$$

$$P(x=1) = \frac{P(x=0)}{1} \approx 0.37$$

$$P(x=2) = \frac{P(x=1)}{2} \approx 0.18$$

$$P(x=3) = \frac{P(x=2)}{3} \approx 0.06$$

$$P(x=4) = \frac{P(x=3)}{4} \approx 0.015$$

The other events represent less than 0.5% of the distribution and are ignored to estimate the theoretical value.

The probability law on the amplitude of the event is a uniform law, from 1 to 10 (which increase the factor from 1 to 10). For one event, the distribution will be uniform. For multiple events, the distribution will corresponds to a sum of uniform distributions. The formula for such sum can be found on http://mathworld.wolfram.com/UniformSumDistribution.html. The pdf formula for a sum of up to 4 uniform distributions defined each between 0 and 1 are displayed below. To have the equivalent for uniform distribution between 0 and 10, one has simply to divide the value of u by 10 in the right member of each of the following four equations.

$$P_{X_1}(u) = \frac{1}{2}[\operatorname{sgn}(1-u) + \operatorname{sgn} u]$$

$$P_{X_1+X_2}(u) = \frac{1}{2}[(-2+u)\operatorname{sgn}(-2+u) - 2(-1+u)\operatorname{sgn}(-1+u) + u \operatorname{sgn} u]$$

$$P_{X_1+X_2+X_3}(u) = \frac{1}{4}[-(-3+u)^2 \operatorname{sgn}(-3+u) + 3(-2+u)^2 \operatorname{sgn}(-2+u) - 3(-1+u)^2 \operatorname{sgn}(-1+u) + u^2 \operatorname{sgn} u]$$

$$P_{X_1+X_2+X_3+X_4}(u) = \frac{1}{12}[(-4+u)^3 \operatorname{sgn}(-4+u) - 4(-3+u)^3 \operatorname{sgn}(-3+u) + 6(-2+u)^3 \operatorname{sgn}(-2+u) - 4(-1+u)^3 \operatorname{sgn}(-1+u) + u^3 \operatorname{sgn} u],$$

From the pdf, it is easy to obtain the CDF by simply integrating the pdf.

The resulting CDF, including up to four events, is thus equivalent to:

$$P(x \le d) = \sum_{i=0}^{\infty} P(x \le d \mid i \text{ events}).P(i \text{ events})$$

while the CCDF is defined as 1 minus the CDF.

The resulting CCDF is displayed below (Figure 20).

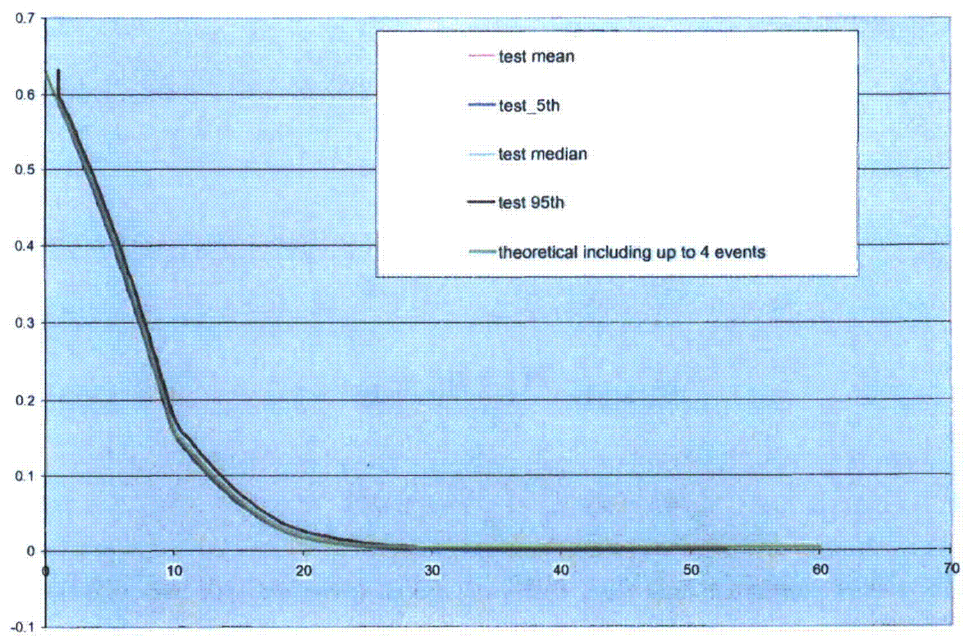


Figure 36. Theoretical CCDF with Multiple Events Taken into Account

Note: There is actually no assumption that the multiple events occur at the same time. The Monte Carlo calculation does not do this assumption (event times and amplitude are sampled separately). However, the test case is rather simple (The dose coming from one event is uniformly distributed and there is no synergism between events. The doses are simply added if there are multiple events). As the dose is a step function (0 before the event and 10 after the event), the theoretical value calculated at the last timestep, 10,000 yr, is simple and corresponds to what is described in the test case.

Table 7.2-12 gives the steps to be performed for Test Case TC-11 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-11, the output of results is written from the EXDOC_LA calculation. There are seven output files produced.

Table 7.2-12. EXDOC_LA Test Case TC-11

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR-04, FR-06.a, FR-06.b, FR-06.d, FR-06.e, FR-06.f, DR-02, OR-02, OR-03, OR-04, OR-05, OR-06, OR-07		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-11.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-11.2	Load the following simplified input files locally from TC-11\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file Law of amplitude file	Files appear locally.
TC-11.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-11.4	Create the information files using the GUI in accordance to specificities of Test TC-11.	A green color indicates the status of the files in the GUI.
TC-11.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time, and mapping on the time of event and amplitude at a given time and for a given LHS realization.	Data_Output files should match file of same name on distribution media TC-11\output.

FR-04 By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.

FR-06.a By satisfactorily calculating and outputting the expected dose file ("_exp.txt") without error, this requirement is met.

FR-06.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.

FR-06.d By satisfactorily calculating and outputting the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.
FR-06.e By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.
FR-06.f By satisfactorily calculating and outputting the mapping of the dose for a given LHS realization file ("_map.txt") without error, this requirement is met.
DR-02 By successfully reading data files produced by GoldSim, this requirement is met.
OR-02 The EXDOC_LA program writes a text file containing all the expected doses, so this technical requirement is met.
OR-03 The EXDOC_LA program writes a text file containing the statistics on the expected doses, so this technical requirement is met.
OR-04 The EXDOC_LA program writes a text file containing a fraction of the interpolated doses for a given LHS realization, so this technical requirement is met.
OR-05 The EXDOC_LA program writes a text file containing the CCDFs of doses at a given time, so this technical requirement is met.
OR-06 The EXDOC_LA program writes a text file containing the statistics of the CCDFs at a given time, so this technical requirement is met.
OR-07 The EXDOC_LA program writes a text file containing a mapping of the dose for a given LHS realization, at a given time, so this technical requirement is met.

7.2.12 Test Case TC-12

TC-12 specifically tests the library EXDOC_LA_MC. This library is used when all aleatory uncertainties are simply sampled using the Monte Carlo approach. The library calculates the expected value at each timestep, and sorts the sampled values to represent the CCDF.

The model used considers an epistemic sample of size 4 and 11 timesteps (from 0.0 to 100.00 with 10.00 yr timesteps). Each epistemic element has an aleatory sample of size 11. The first epistemic sample element has the following aleatory sample of size 11 (First line corresponds to the timestep and is not part of the sample element).

Table 1. Output Data for the 1st Epistemic Element (with an Aleatory Sample of Size 11)

time	(A1,E1)(*)	(A2,E1)	(A3,E1)	(A4,E1)	(A5,E1)	(A6,E1)	(A7,E1)	(A8,E1)	(A9,E1)	(A10,E1)	(A11,E1)
0	0	0	0	0	0	0	0	1	0	0	0
10	0	0	0	0.9	0	0	0	1	0	0	0
20	0.8	0	0	0.9	0	0	0	1	0	0	0
30	0.8	0	0	0.9	0	0	0	1	0	0	0.7
40	0.8	0	0	0.9	0	0.6	0	1	0	0	0.7
50	0.8	0	0	0.9	0.5	0.6	0	1	0	0	0.7
60	0.8	0.4	0	0.9	0.5	0.6	0	1	0	0	0.7
70	0.8	0.4	0	0.9	0.5	0.6	0.3	1	0	0	0.7
80	0.8	0.4	0.2	0.9	0.5	0.6	0.3	1	0	0	0.7
90	0.8	0.4	0.2	0.9	0.5	0.6	0.3	1	0.1	0	0.7
100	0.8	0.4	0.2	0.9	0.5	0.6	0.3	1	0.1	0	0.7

(*)Ai designates the element i of the aleatory sample. E1 indicates that it corresponds to element 1 of the epistemic sample.

The aleatory sample has been constructed this way:

One element of the sample (#8) has been constructed by supposing that solution was always equal to 1. In the next element, one supposes that a non-0 value is obtained one timestep later and the value is decreased by 0.1, and so on (in the example, it corresponds to sample element #4, #1, #11, #6, #5, #2, #9, #3, and #10). Please note that the order is not important and each aleatory sample element has been randomly assigned to be sure that the result did not depend on the order.

The values have been randomly assigned to test the validity of the Monte Carlo method.

Each other epistemic element is constructed the same way but with each value multiplied by 2, with respect to the precedent epistemic element (in other words, results are multiplied by 2 for LHS2, by 4 for LHS3, and by 8 for LHS4, with respect to LHS1).

The expected dose at each time step can be estimated the following way:

Let t_i be the timestep index (from 1 to 11). The sum over all aleatory elements for LHS1 is equal to:

$$S(t_i, LHS_1) = \frac{1}{10}\sum_{k=1}^{10} k - \frac{1}{10}\sum_{k=1}^{\max(10-ti,0)} k \quad . \qquad \text{(Equation 11)}$$

This expression can be estimated as follows:

$$\begin{aligned} S(t_i, LHS_1) &= \frac{1}{10}\left(\frac{10*11}{2}\right) - \max\left(0, \frac{(10-t_i)*(11-t_i)}{20}\right) \\ &= 5.5 - \max\left(0, \frac{(10-t_i)*(11-t_i)}{20}\right) \\ &= \min\left(5.5, 5.5 - \frac{(10-t_i)*(11-t_i)}{20}\right) \\ &= \min\left(5.5, 5.5 - \frac{110-21t_i+t_i^2}{20}\right) \\ &= \min\left(5.5, 5.5 - 5.5 + 1.05t_i - \frac{t_i^2}{20}\right) \\ &= \min\left(5.5, 1.05t_i - \frac{t_i^2}{20}\right) \end{aligned} \qquad \text{(Equation 12)}$$

To calculate the expected value, one has to divide the result by the aleatory sample size (11) to obtain

$$E(t_i, LHS_1) = \min\left(0.5, \frac{1.05}{11}t_i - \frac{t_i^2}{220}\right). \qquad \text{(Equation 13)}$$

The expected value for the other epistemic elements is respectively multiplied by 2, 4, and 8.

The result is, thus, a second order polynomial whose values at t=100,000 yr is respectively 0.5, 1, 2, and 4 for the four LHS elements (Figure 21).

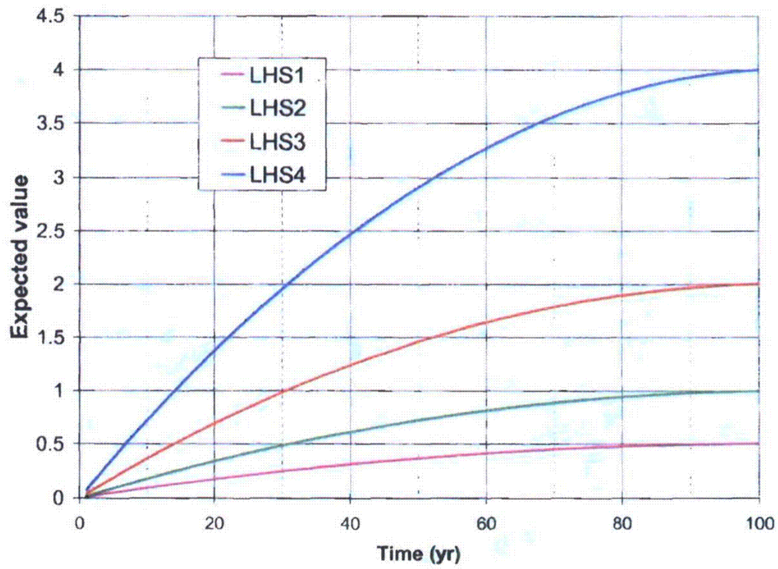


Figure 37. Theoretical Results for Expected Value in TC-12

As for 100 yr, for an aleatory set of LHS1 and 11 values equally distributed between 0 and 1, the CCDF results on a straight line from (X=0, Y=1) to (X=1, Y=0). For other LHS elements, the end point changes respectively to (X=2,Y=0), (X=4,Y=0), and (X=8,Y=0), as displayed in Figure 22.

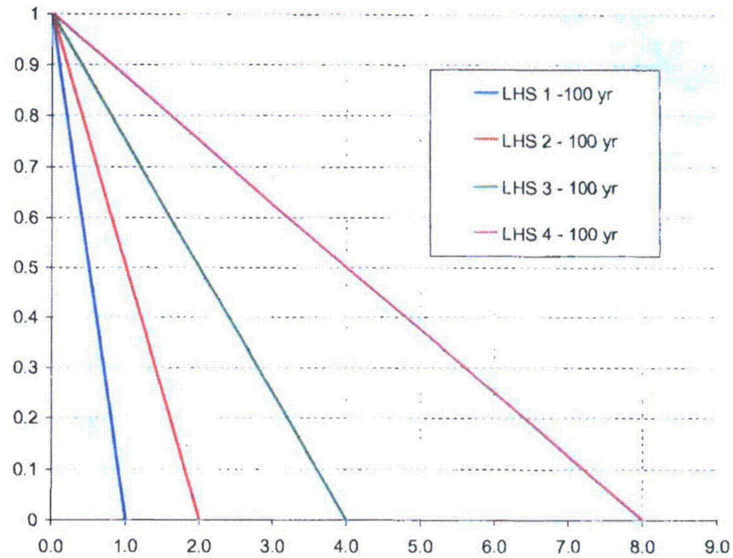


Figure 38. Theoretical Value for CCDF in TC-12

Table 7.2-13 gives the steps to be performed for Test Case TC-12 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-12, the output of results is written from the EXDOC_LA calculation. There are five output files produced.

Table 7.2-13. EXDOC_LA Test Case TC-12

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR_MC-01, FR_MC-02, FR_MC-03, FR_MC-04, FR_MC-05.a, FR_MC-05.b, FR_MC-05.c, FR_MC-05.d		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-12.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-12.2	Load the following simplified input files locally from TC-12\input on the distribution media: Dose files Quantile file	Files appear locally.
TC-12.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-12.4	Create the information files using the GUI in accordance to specificities of Test TC-12.	A green color indicates the status of the files in the GUI.
TC-12.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time.	Data_Output files should match file of same name on distribution media TC-12\output.

FR_MC-01	By satisfactorily reading the input control file (info_mc.dat) without error, this requirement is met.
FR_MC-02	By satisfactorily reading the input parameter file (expc_mc.dat) without error, this requirement is met.
FR_MC-03	By satisfactorily reading the input parameter file (ccdf_mc.dat) without error, this requirement is met.
FR_MC-04	By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.
FR_MC-05.a	By satisfactorily calculating and outputting the expected regulatory dose file ("_exp.txt) without error, this requirement is met.
FR_MC-05.b	By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.
FR_MC-05.c	By satisfactorily calculating and outputting the CCDF at a given time file without error, this requirement is met.
FR_MC-05.d	By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.

7.2.13 Test Case TC-13

TC-13 specifically tests the library EXDOC_LA_CV. This library uses convolution to assemble the results. It is used for the Nominal early failure scenario. The library calculates the expected value at each timestep and estimates CCDF using the Monte Carlo approach.

The test case is designed as follows:

Reference dose is defined as linear between 0 and 10,000 yr with value equal to 1 at 10,000 yr.

Four LHS elements are considered, multiplying respectively the dose by 1, 2, 3, and 4.

Three bins are considered with fractions equal to 0.2, 0.6, and 0.2. The results are respectively multiplied by 5, 2, and 4 for each bin (the expected value will be multiplied by 3).

Two WP types are considered with fractions equal to 0.8 and 0.2. The results are respectively multiplied by 1 and 11 (the expected value will be multiplied by 3).

The drip fractions are equivalent for each bin but are varying depending on the epistemic set. They are equal to 0.1, 0.2, 0.4, and 0.8. The reference is multiplied by 4 in a dripping environment and by 1 in a non-dripping environment.

The resulting four expected doses should be linear with time, and the value at 10,000 yr should be close to the following theoretical values.

$$\text{LHS1: } E(1) = [0.1*4+0.9*1]*3*3*1 = 11.7$$

$$\text{LHS2: } E(2) = [0.2*4+0.8*1]*3*3*2 = 28.8$$

$$\text{LHS3: } E(3) = [0.4*4+0.6*1]*3*3*3 = 59.4$$

$$\text{LHS4: } E(4) = [0.8*4+0.2*1]*3*3*4 = 122.4$$

Based on the formula

$$E(i) = \left[f_{drip,i} * d_{drip} + (1.- f_{drip,i})* d_{nodrip}\right]* E[bin]* E[WP]* e_i \qquad \text{(Equation 14)}$$

where

- $f_{drip,i}$ represents the fraction of dripping region for LHS #i
- d_{drip} represents the reference dose multiplied by the dripping effect
- d_{nodrip} represents the reference dose multiplied by the no-dripping effect
- $E[bin]$ is the expected effect of binning
- $E[WP]$ is the expected effect of WP type
- e_i is the effect of epistemic uncertainty (other than drip fraction).

Theoretical results are displayed in Figure 23.

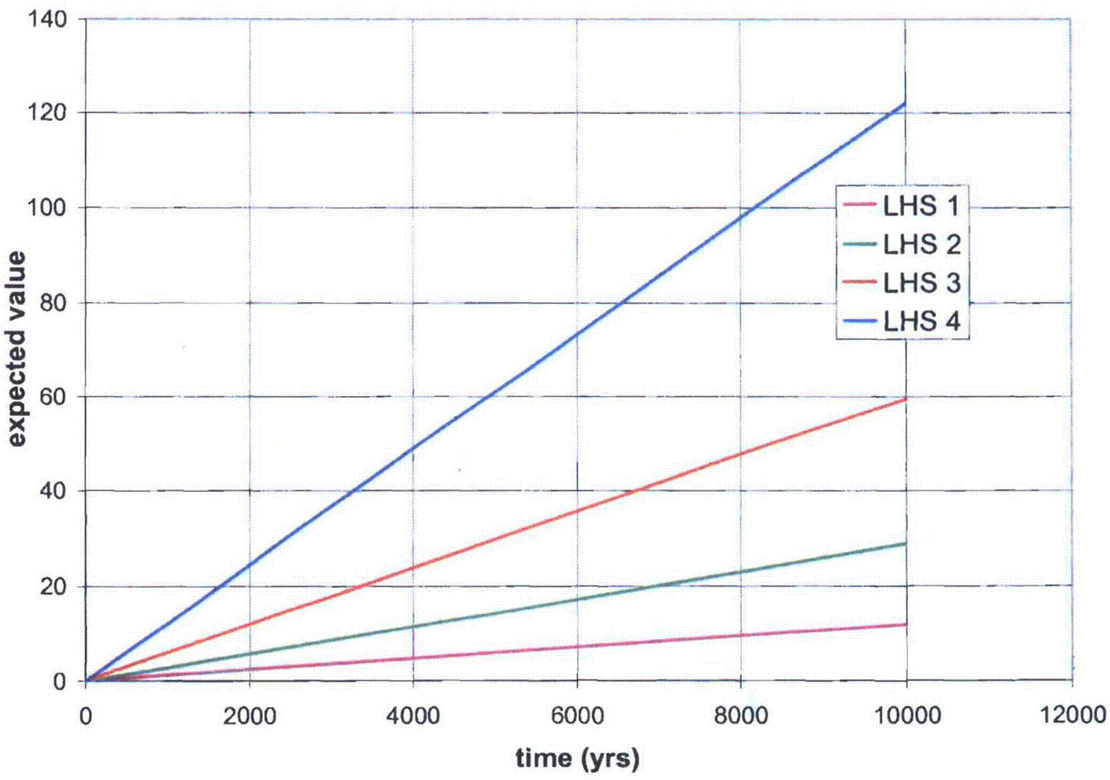


Figure 39. Theoretical Results for Expected Dose for Tc-13

CCDF is estimated using the Monte Carlo technique. The CCDF will be verified at time t=10,000 by estimating the expected value from the CCDF. It consists of summing all values and assigning them the same weight (=1/n, where n designed the aleatory sample size).

Table 7.2-14 gives the steps to be performed for Test Case TC-13 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-13, the output of results is written from the EXDOC_LA calculation. There are five output files produced.

Table 7.2-14. EXDOC_LA Test Case TC-13

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR_CV-01, FR_CV-02, FR_CV-03, FR_CV-04, FR_CV-05.a, FR_CV-05.b, FR_CV-05.c, FR_CV-05.d, FR_CV-05.e, IR-07, IR-08, IR-09		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-13.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-13.2	Load the following simplified input files locally from TC-13\input on the distribution media: Dose files Lambda file Quantile file Bin fraction file WP fraction file Drip fraction file	Files appear locally.
TC-13.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-13.4	Create the information files using the GUI in accordance to specificities of Test TC-13.	A green color indicates the status of the files in the GUI.
TC-13.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time.	Data_Output files should match file of same name on distribution media TC-13\output.

FR_CV-01 By satisfactorily reading the input control file (info_cv.dat) without error, this requirement is met.

FR_CV-02 By satisfactorily reading the input parameter file (expc_cv.dat) without error, this requirement is met.

FR_CV-03 By satisfactorily reading the input parameter file (ccdf_cv.dat) without error, this requirement is met.

FR_CV-04 By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.

FR_CV-05.a	By satisfactorily calculating and outputting the expected dose file ("_exp.txt) without error, this requirement is met.
FR_CV-05.b	By satisfactorily convoluting the expected dose over bins, wp type and/or dripping conditions without error, this requirement is met.
FR_CV-05.c	By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.
FR_CV-05.d	By satisfactorily calculating and outputting the CCDF at a given time file without error, this requirement is met.
FR_CV-05.e	By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.
IR-07	By producing the expected output showing that the appropriate fractions were read from the fraction of bins file, this requirement is met.
IR-08	By producing the expected output showing that the appropriate fractions were read from the fraction of dripping conditions file, this requirement is met.
IR-09	By producing the expected output showing that the appropriate fractions were read from the fraction of WP file, this requirement is met.

7.2.14 Test Case TC-14

TC-14 specifically tests the library EXDOC_LA_MCT. This library uses a quadrature to integrate over the time of event and a Monte Carlo method for all other aleatory uncertainty. It is used for the igneous eruptive scenario. The library calculates the expected value at each timestep and estimates CCDF using the Monte Carlo approach.

The test case is designed as follows:

Reference dose is defined as equal to 0 before the event and 1 after the event.

Four LHS elements are considered, multiplying respectively the dose by 1, 2, 5, and 8.

The amplitude of the event (number of WPs destroyed) is considered to be uniformly distributed between 0 and 20 (has an effect to multiply the expected value by 10.0).

The time of study is 10,000 yr. The frequency of events is 10^{-5}/yr (has an effect of multiplying expected value by 0.1).

We have three realizations of the set of aleatory variables. They multiply the value by respectively 0.1, 1, and 10 (this has an effect of multiplying the expected value by 3.7).

The time of events considered is T=0; 100; 500; 1,000; 5,000; and 10,000.

The resulting four expected doses should be linear with time, and the value at 10,000 yr should be close to the following theoretical values:

$$\text{LHS1: } E(1) = 1*10*0.1*3.7*1 = 3.7$$

$$\text{LHS2: } E(2) = 1*10*0.1*3.7*2 = 7.4$$

$$\text{LHS3: } E(3) = 1 * 10 * 0.1 * 3.7 * 5 = 18.5$$

$$\text{LHS4: } E(4) = 1 * 10 * 0.1 * 3.7 * 8 = 29.6$$

Based on the formula

$$E(i) = d * E[lambda * T] * E[amplitude] * a * e_i \qquad \text{(Equation 15)}$$

where

- d represents the reference dose multiplied by the dripping effect
- $E[lambda * T]$ is the expected effect time of study and lambda
- $E[amplitude]$ is the expected effect of amplitude
- a represents the aleatory uncertainty influence
- e_i is the effect of epistemic uncertainty.

Theoretical results are displayed in Figure 24.

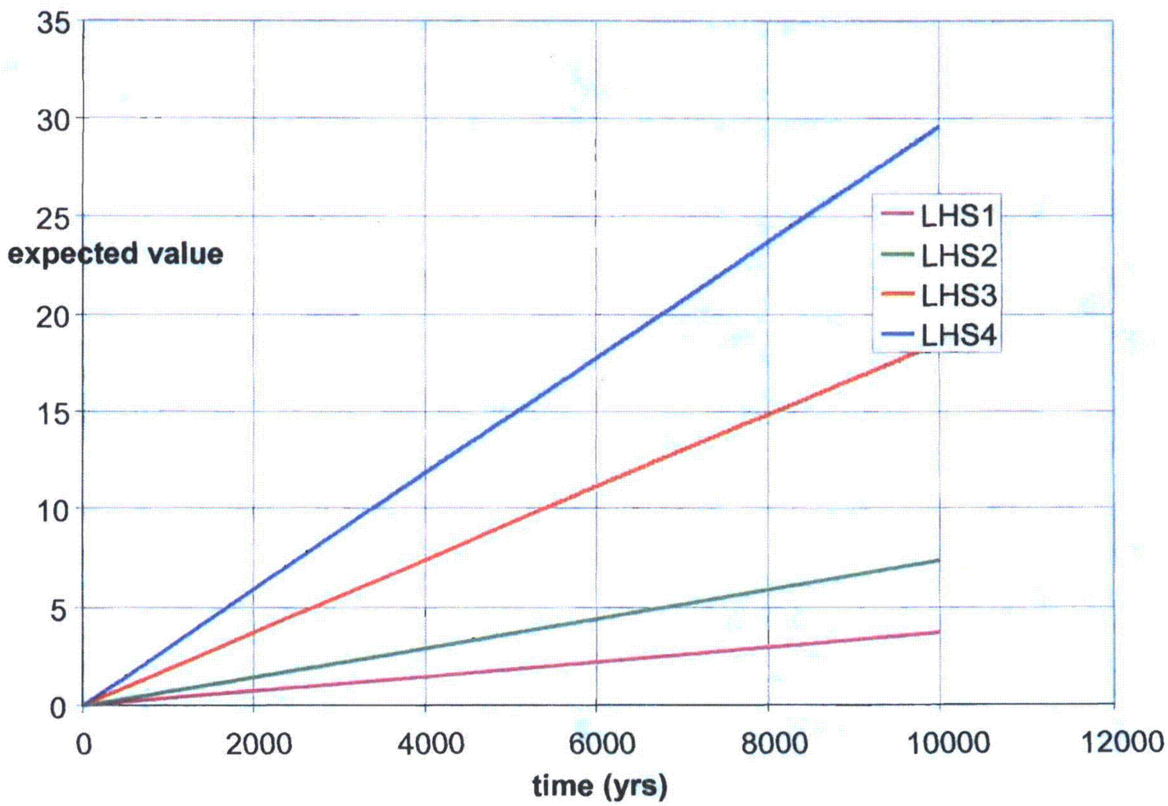


Figure 40. Theoretical Results for TC-14

CCDF is estimated by using the Monte Carlo technique. The CCDF will be verified at time t=10,000 by estimating the expected value from the CCDF. It consists of summing all values and assigning them the same weight (=1/n, where n designed the aleatory sample size).

Table 7.2-15 gives the steps to be performed for Test Case TC-14 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-14, the output of results is written from the EXDOC_LA calculation. There are five output files produced.

Table 7.2-15. EXDOC_LA Test Case TC-14

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR_MCT-01, FR_MCT-02, FR_MCT-03, FR_MCT-04, FR_MCT-05.a, FR_MCT-05.b, FR_MCT-05.c, FR_MCT-05.d		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-14.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-14.2	Load the following simplified input files locally from TC-14\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Quantile file	Files appear locally.
TC-14.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-14.4	Create the information files using the GUI in accordance to specificities of Test TC-14.	A green color indicates the status of the files in the GUI.
TC-14.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time.	Data_Output files should match file of same name on distribution media TC-14\output.

FR_MCT-01 By satisfactorily reading the input control file (info_mct.dat) without error, this requirement is met.

FR_MCT-02 By satisfactorily reading the input parameter file (expc_mct.dat) without error, this requirement is met.

FR_MCT-03 By satisfactorily reading the input parameter file (ccdf_mct.dat) without error, this requirement is met.

FR_MCT-04 By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.

FR_MCT-05.a By satisfactorily calculating and outputting the expected dose file ("_exp.txt) without error, this requirement is met.

FR_MCT-05.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.
FR_MCT-05.c By satisfactorily calculating and outputting the CCDF at a given time file without error, this requirement is met.
FR_MCT-05.d By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.

7.2.15 Test Case TC-15

TC-15 specifically tests the library EXDOC_LA_FD. This library uses convolution to assemble the results and integrate over time of event and amplitude of event. It is used for the seismic FD scenario. The library calculates the expected value at each timestep and estimates CCDF using the Monte Carlo approach.

The test case is designed to include the reference dose as being defined as equal to 0 before the event and 1 after the event.

The annual frequency for each WP type is considered identical and is designed as follows:

With a frequency of 0.99999, no packages of a given type are destroyed.
With a frequency of 5.0×10^{-6}, 10 packages of a given type are destroyed.
With a frequency of 2.5×10^{-6}, 100 packages of a given type are destroyed.
With a frequency of 2.0×10^{-6}, 1000 packages of a given type are destroyed.
With a frequency of 5.0×10^{-5}, 10,000 packages of a given type are destroyed.
(The annual expected number of WPs of a given type destroyed is equal to 0.0073.)

The fraction of surface area damaged is log-uniformly distributed between 10^{-2} and 1.
(The expected fraction of surface area damaged is equal to ~ 0.215.)

The simulation is done up to 10,000 yr.

Four LHS elements are considered, multiplying respectively the dose by 1, 2, 3, and 4.

Three bins are considered with fractions equal to 0.2, 0.6, and 0.2. The results are respectively multiplied by 5, 2, and 4 for each bin (the expected value will be multiplied by 3).

Two WP types are considered. We suppose that both WP types are present at each location considered. The results are respectively multiplied by 1 and 11 (the expected value will be multiplied by 12).

The drip fractions are equivalent for each bin but are varying depending on the epistemic set. They are equal to 0.1, 0.2, 0.4, and 0.8. The reference is multiplied by 4 in a dripping environment and by 1 in a non-dripping environment.

The resulting four expected doses should be linear with time, and the value at 10,000 yr should be close to the following theoretical values.

LHS1: $E(1) = (0.1*4 + 0.9*1)*3*12*0.215*0.0073*10000*1 \approx 735$

LHS2: $E(2) = (0.2*4 + 0.8*1)*3*12*0.215*0.0073*10000*2 \approx 1808$

LHS3: $E(3) = (0.4*4 + 0.6*1)*3*12*0.215*0.0073*10000*3 \approx 3729$

LHS4: $E(4) = (0.8*4 + 0.2*1)*3*12*0.215*0.0073*10000*4 \approx 7683$

Based on the formula

$$E(i) = (f_{drip,i} * d_{drip} + (1. - f_{drip,i}) * d_{nodrip}) * E[bin] * E[WP] * E[SAD] * E[nWPD] * T * e_i$$

(Equation 16)

where

- $f_{drip,i}$ represents the fraction of dripping region for LHS #i
- d_{drip} represents the reference dose multiplied by the dripping effect
- d_{nodrip} represents the reference dose multiplied by the no-dripping effect
- $E[bin]$ is the expected effect of binning
- $E[WP]$ is the expected effect of WP type
- $E[SAD]$ is the expected effect of the surface area damaged
- $E[nWPD]$ is the annual expected number of WPs destroyed
- T is the timestep for which the expected value is calculated (equal to T=10,000 yr in the example)
- e_i is the effect of epistemic uncertainty (other than drip fraction).

Theoretical results are displayed in Figure 41.

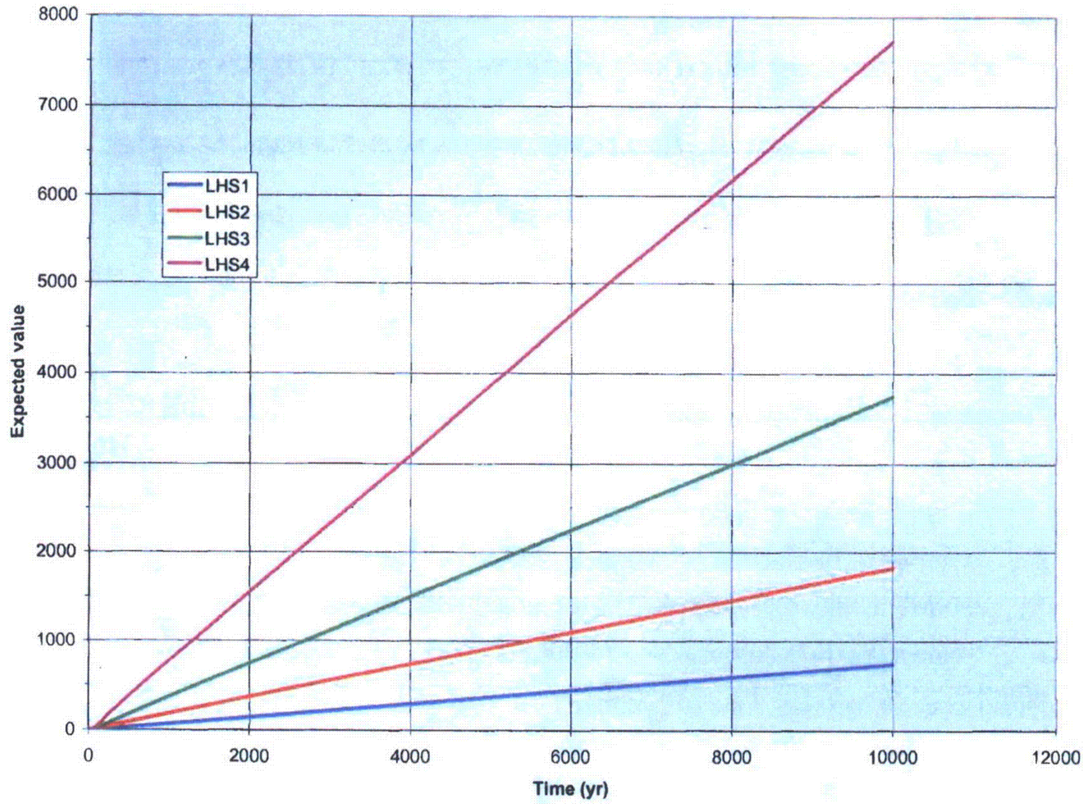


Figure 41. Theoretical Results for Expected Dose for TC-15

Table 7.2-16 gives the steps to be performed for Test Case TC-15 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-15, the output of results is written from the EXDOC_LA calculation. There are five output files produced.

Table 7.2-16. EXDOC_LA Test Case TC-15

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR_FD-01, FR_FD-02, FR_FD-03, FR_FD-04, FR_FD-05.a, FR_FD-05.b, FR_FD-05.c, FR_FD-05.d, IR-03, IR-04, IR-07, IR-08, IR-09, IR-10		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-15.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.

TC-15.2	Load the following simplified input files locally from TC-15\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Amplitude distribution files Quantile file Bin fraction file WP fraction file Drip fraction file	Files appear locally.
TC-15.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-15.4	Create the information files using the GUI in accordance to specificities of Test TC-15.	A green color indicates the status of the files in the GUI.
TC-15.5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time.	Data_Output files should match file of same name on distribution media TC-15\output.

FR_FD-01 By satisfactorily reading the input control file (info_fd.dat) without error, this requirement is met.

FR_FD-02 By satisfactorily reading the input parameter file (expc_fd.dat) without error, this requirement is met.

FR_FD-03 By satisfactorily reading the input parameter file (ccdf_fd.dat) without error, this requirement is met.

FR_FD-04 By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.

FR_FD-05.a By satisfactorily calculating and outputting the expected dose file ("_exp.txt) without error, this requirement is met.

FR_FD-05.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.

FR_FD-05.c By satisfactorily calculating and outputting the CCDF at a given time file without error, this requirement is met.

FR_FD-05.d By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.

IR-03 The EXDOC_LA program reads an ASCII text formatted time of event file that contains a list of time of events, so this technical requirement is met.

IR-04 The EXDOC_LA program reads an ASCII text formatted amplitude file that contains a list of amplitudes, so this technical requirement is met.

IR-07 By producing the expected output showing that the appropriate fractions were read from the fraction of bins file, this requirement is met.

IR-08 By producing the expected output showing that the appropriate fractions were read from the fraction of dripping conditions file, this requirement is met.

IR-09 By producing the expected output showing that the appropriate fractions were read from the fraction of WP file, this requirement is met.

IR-10 By producing the expected output showing that the appropriate probabilities of drip-shield failures at each time-step were read, this requirement is met.

7.2.16 Test Case TC-16

TC-16 specifically tests the library EXDOC_LA_SE. This library uses the Monte Carlo approach to determine an expected value for the seismic GMD modeling case at 10,000 yr, supposing synergisms between events. The library calculates the expected value at each timestep and estimates CCDF using the Monte Carlo approach.

The synergism between multiple events is accounted for by using a different distribution of surface area damaged once the package has degraded interiors (this status is reached once there is one seismic event causing any damage to the package).

The test case is designed as follow:

The dose is supposed to be equal to 0 before the event and 1 after the event (no epistemic uncertainty). The frequency of the event is fixed to 10^{-4} / yr.

The amplitude of event (surface area damaged) for intact packages is uniformly distributed between 10 and 30, with an expected value of 20.

The epistemic uncertainty is represented by creating a sample of size 4, whose values are multiplied respectively by 1, 2, 3, and 4.

The amplitude of event (surface area damaged) for degraded packages is uniformly distributed between 20 and 40, with an expected value of 30.

Ten files of pseudo doses have been generated for the following time of events:

10 yr; 100 yr; 200 yr; 600 yr; 1,000 yr; 2,000 yr; 3,000 yr; 5,000 yr; 7,000 yr; and 10,000 yr.

By using the Monte Carlo method, we allow multiple events in expected doses.

The first step in the derivation of the theoretical CCDF is to calculate the probability of multiple events. The events follow a Poisson process with an expected number of events given the time period [0, 10,000 yr] equal to 1 over the time considered. The probabilities of having 0 to 4 events are given below:

$$P(x=0) = e^{-1} \approx 0.37$$

$$P(x=1) = \frac{P(x=0)}{1} \approx 0.37$$

$$P(x=2) = \frac{P(x=1)}{2} \approx 0.18$$

$$P(x=3)=\frac{P(x=2)}{3}\approx 0.06$$

$$P(x=4)=\frac{P(x=3)}{4}\approx 0.015.$$

The other events represent less than 0.5% of the distribution and are ignored to estimate the theoretical value.

The expected value corresponds to the sum of expected values supposing one event, two events, and so on. For the theoretical value, only up to 4 events are considered. The influence of amplitude will be respectively equal to 20, 50, 80, and 110. (20 if there is one event, 20+30 if there are 2 events, and 20+(n-1)*30 if there are n events.)

For first epistemic sample element, we have an expected value equal to:

$$\begin{aligned}E_1(D) &= P(X=0)*0+P(X=1)*D_1+P(X=2)*D_2+P(X=3)*D_3+P(X=4)*D_4+\varepsilon\\ &\approx (0.37*0)+(0.37*20)+(0.18*50)+(0.06*80)+(0.015*110)+\varepsilon\\ &\approx 23.15+\varepsilon\end{aligned}$$

The result will be four expected values linear over time, equal to 0 at t=0 yr, and respectively equal to 23.15, 46.29, 69.44, and 92.58. Theoretical results are displayed in Figure 42.

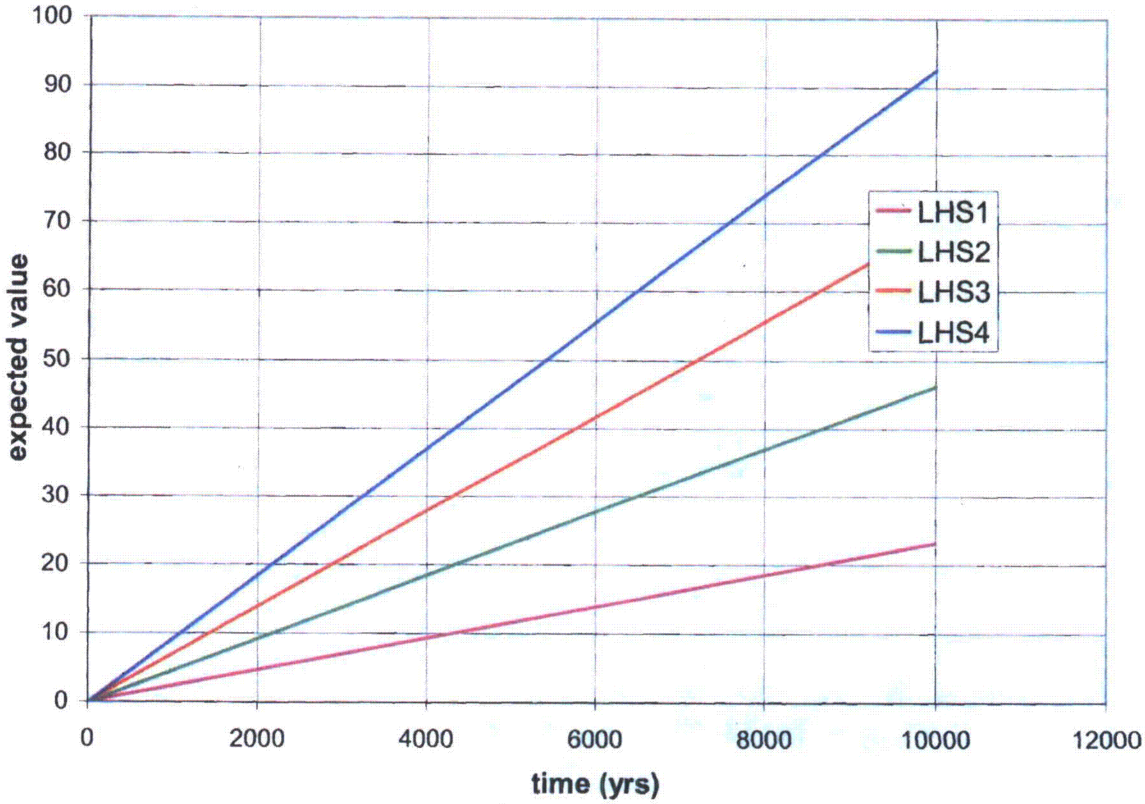


Figure 42. Theoretical Expected Value for TC-16

Table 7.2-17 gives the steps to be performed for Test Case TC-16 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-16, the output of results is written from the EXDOC_LA calculation. There are five output files produced.

Table 7.2-17. EXDOC_LA Test Case TC-16

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR_SE-01, FR_SE-02, FR_SE-03, FR_SE-04, FR_SE-05.a, FR_SE-05.b, FR_SE-05.c, FR_SE-05.d		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-16. 1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.

TC-16. 2	Load the following simplified input files locally from TC-16\input on the distribution media: Dose files Lambda file Time of event file Amplitude file Amplitude distribution files Quantile file	Files appear locally.
TC-16. 3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-16. 4	Create the information files using the GUI in accordance to specificities of Test TC-16.	A green color indicates the status of the files in the GUI.
TC-16. 5	Compare output files: Expected doses, statistics on the expected doses, doses for a given LHS realization, CCDFs at a given time, statistics on CCDFs at a given time.	Data_Output files should match file of same name on distribution media TC-16\output.

FR_SE-01 By satisfactorily reading the input control file (info_se.dat) without error, this requirement is met.

FR_SE-02 By satisfactorily reading the input parameter file (expc_se.dat) without error, this requirement is met.

FR_SE-03 By satisfactorily reading the input parameter file (ccdf_se.dat) without error, this requirement is met.

FR_SE-04 By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.

FR_SE-05.a By satisfactorily calculating and outputting the expected dose file ("_exp.txt) without error, this requirement is met.

FR_SE-05.b By satisfactorily calculating and outputting the statistics on the expected dose file ("_stat.txt") without error, this requirement is met.

FR_SE-05.c By satisfactorily calculating and outputting the CCDF at a given time file without error, this requirement is met.

FR_SE-05.d By satisfactorily calculating and outputting the statistics on the CCDF at a given time file ("_ccdf.txt") without error, this requirement is met.

7.2.17 Test Case TC-17

TC-17 specifically tests the library EXDOC_LA_TR. This library separates the information contained in a single GoldSim [DIRS 169844] output file into several input files that are formatted for EXDOC. The test case is designed as follows:

An input file has been created. It has 26 rows and 48 columns.

The first two rows correspond to comments, and the other rows represent an array.

The first column of the array gives the timestep. Other arrays are defined in the following way:

Each group of 12 columns represents an epistemic set (the epistemic sample size = 4).

The 12 columns vary according to 2 aleatory variables as described below for LHS4.

Variation over aleatory 2

Comment 1
Comment 2

0.0	64	640	6400	64000	192	1920	19200	192000	320	3200	32000	320000
10.0	65	641	6401	64001	193	1921	19201	192001	321	3201	32001	320001
20.0	66	642	6402	64002	194	1922	19202	192002	322	3202	32002	320002
30.0	67	643	6403	64003	195	1923	19203	192003	323	3203	32003	320003
40.0	68	644	6404	64004	196	1924	19204	192004	324	3204	32004	320004
50.0	69	645	6405	64005	197	1925	19205	192005	325	3205	32005	320005
60.0	70	646	6406	64006	198	1926	19206	192006	326	3206	32006	320006
70.0	71	647	6407	64007	199	1927	19207	192007	327	3207	32007	320007
80.0	72	648	6408	64008	200	1928	19208	192008	328	3208	32008	320008
90.0	73	649	6409	64009	201	1929	19209	192009	329	3209	32009	320009
100.0	74	650	6410	64010	202	1930	19210	192010	330	3210	32010	320010
110.0	75	651	6411	64011	203	1931	19211	192011	331	3211	32011	320011
120.0	76	652	6412	64012	204	1932	19212	192012	332	3212	32012	320012
130.0	77	653	6413	64013	205	1933	19213	192013	333	3213	32013	320013
140.0	78	654	6414	64014	206	1934	19214	192014	334	3214	32014	320014
150.0	79	655	6415	64015	207	1935	19215	192015	335	3215	32015	320015
160.0	80	656	6416	64016	208	1936	19216	192016	336	3216	32016	320016
170.0	81	657	6417	64017	209	1937	19217	192017	337	3217	32017	320017
180.0	82	658	6418	64018	210	1938	19218	192018	338	3218	32018	320018
190.0	83	659	6419	64019	211	1939	19219	192019	339	3219	32019	320019
200.0	84	660	6420	64020	212	1940	19220	192020	340	3220	32020	320020
210.0	85	661	6421	64021	213	1941	19221	192021	341	3221	32021	320021
220.0	86	662	6422	64022	214	1942	19222	192022	342	3222	32022	320022
230.0	87	663	6423	64023	215	1943	19223	192023	343	3223	32023	320023
240.0	88	664	6424	64024	216	1944	19224	192024	344	3224	32024	320024

Time of event

Variation over aleatory 1

The program will split this file into 12 separate files with the following requirements:

- The name of the output files will be prefix-xxx-yyy.txt, where xxx designates aleatory 2 and yyy designates aleatory 1.
- Aleatory 1 results will be numbered 1, 2, 3, and 4. Aleatory 2 results will be numbered 1, 3, and 5.

The results should give 12 files named: prefix-001-001.txt, prefix-002-001.txt, prefix-003-001.txt, prefix-004-001.txt, prefix-001-003.txt, prefix-002-003.txt, prefix-003-003.txt, prefix-004-003.txt, prefix-001-005.txt, prefix-002-005.txt, prefix-003-005.txt and prefix-004-005.txt.

The last element of the files should be, respectively, 88, 664, 6424, 64024, 216, 1944, 19224, 192024, 344, 3224, 32024, and 32024.

Table 7.2-18 gives the steps to be performed for Test Case TC-17 and acceptance criteria for each of the steps.

After Step 5 of Test Case TC-17, the output of results is written from the EXDOC_LA calculation. There are five output files produced.

Table 7.2-18. EXDOC_LA Test Case TC-17

Platform/OS: Windows XP, Windows 2000, Windows Server 2003		
Description of Test: A simplified data input will be used with a format identical to GoldSim [DIRS 169844] output on a local PC to test the inputs/outputs of the EXE and the system compatibility.		
Requirements Tested: FR_TR-01, FR_TR-02.a, FR_TR-02.b, OR-08		
Test Case Acceptance Criteria: All files read without error. Output produced as specified.		
Test Step	**Description of Step**	**Step Acceptance Criteria**
TC-17.1	Load EXDOC_LA.exe and DLL files from the distribution media locally on a Windows XP PC.	Files appear locally.
TC-17.2	Load the following simplified input files locally from TC-17\input on the distribution media: Dose files	Files appear locally.
TC-17.3	Start the EXDOC_LA.exe execution.	Execution completes without error message.
TC-17.4	Create the information files using the GUI in accordance to specificities of Test TC-17.	A green color indicates the status of the files in the GUI.
TC-17.5	Compare output files: doses.	Data_Output files should match file of same name on distribution media TC-17\output.

FR_TR-01 By satisfactorily reading the input control file (info_tr.dat) without error, this requirement is met.

FR_TR-02.a By satisfactorily processing data from multiple times and multiple realizations without error, this requirement is met.

FR_TR-02.b By satisfactorily creating separate files from the GoldSim file, this requirement is met.

OR-08 By satisfactorily creating separate files from the GoldSim file, this requirement is met.

7.3 Test Case Log

Table 7.3-1. Test Case Log

Test Case	Completed (Pass/Fail)	Tester Initials	Date
TC-01			
TC-02			
TC-03			
TC-04			
TC-05			
TC-06			
TC-07			
TC-08			
TC-09			
TC-10			
TC-11			
TC-12			
TC-13			
TC-14			
TC-15			
TC-16			
TC-17			
Tester Name (Print)			
Tester Sign			

7.4 Testing Approach

The general category of the tests described in Section 5.2 will test the EXDOC_LA according to the RD. Validation of Test Cases TC-01 to TC-17 are straightforward comparisons of input and output files. Test TC-11 is a verification test that satisfactory operation occurs on the TSPA computers with full sized data files.

Each of the tests described above is an integrated test of the software designed to test one or more of the input, output, or functional requirements specified in the RD.

8. REFERENCES/ATTACHMENTS

169844 GoldSim V. 8.02. 2004. WINDOWS 2000. STN: 10344-8.02-00.

166226 GoldSim Technology Group. 2003. *User's Guide, GoldSim Probabilistic Simulation Environment.* Version 8. 01. Redmond, Washington: Golder Associates. TIC: 255170.

174599 Requirements Document (RD) for EXDOC_LA Version 2.0 (Document ID: 11193-RD-2.0-00)

103316 Press, W.H.; Teukolsky, S.A.; Vetterling, W.T.; and Flannery, B.P. 1992. *Numerical Recipes in Fortran* 77, *The Art of Scientific Computing.* Volume 1 of *Fortran Numerical Recipes.* 2nd Edition. Cambridge, United Kingdom: Cambridge University Press. TIC: 243606.

174603 BSC (Bechtel SAIC Company) 2005. *Requirements Traceability Matrix for: EXDOC_LA V1.0. Document* ID: 11193-RTM-1.0-00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20050622.0009; MOL.20050622.0002.

163475 Helton, J.C. and Davis, F.J. 2002. *Latin Hypercube Sampling and the Propagation of Uncertainty in Analyses of Complex Systems.* SAND2001-0417. Albuquerque, New Mexico: Sandia National Laboratories. TIC: 254367.

174601 DOE (U.S. Department of Energy) 2005. *User Information for: EXDOC_LA V1.0.* Document ID: 11193-UID-1.0-00. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20050622.0007.

EXDOC_LA Software Configuration Control Request (SCCR) 11193-2.0-00

EXDOC_LA Modify In-Process Software Configuration Control Request (SCCR) 11193-2.0-00 (Dated 2-8-07)

EXDOC_LA Modify In-Process Software Configuration Control Request (SCCR) 11193-2.0-00 (Dated 6-11-07)

EXDOC_LA Modify In-Process Software Configuration Control Request (SCCR) 11193-2.0-00 (Dated 6-14-07)

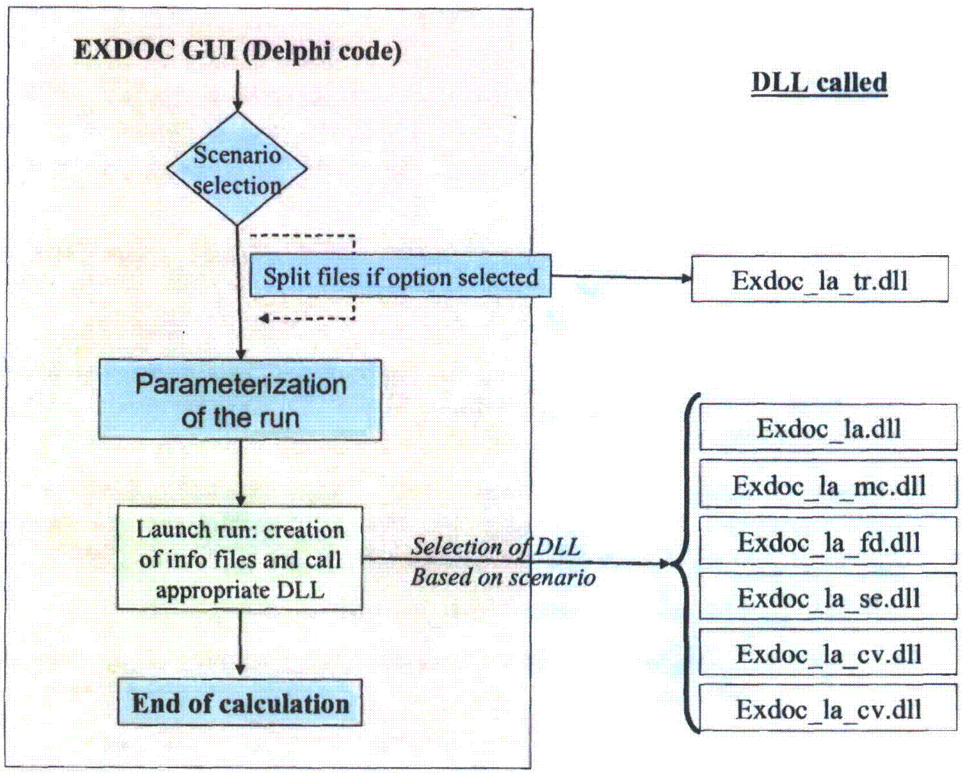
EXDOC_LA Modify In-Process Software Configuration Control Request (SCCR) 11193-2.0-00 (Dated 7-10-07)

IM-PRO-003, *Software Management*, Sandia National Laboratories

IM-PRO-004, *Qualification of Software*, Sandia National Laboratories

APPENDIX A – SOURCE CODE STRUCTURE

The structure of the source code is show below.



A classical run of EXDOC once the GUI is launched is described as:

1. One can if necessary call the library Exdoc_la_tr.dll in order to split the Goldsim file into several files that can be read by the other DLLs – a new window will appear, in which the user has to fill each field in concordance with functional requirement FR_TR-01 (note that if the values selected are dependent on the scenario chosen, the DLL is by itself independent on a specific scenario)

2. The user select a scenario class.

3. Based on the scenario, the user fill (manually or automatically) the information specific for the run. The fields of four windows have to be updated, in concordance to the functional requirements associated with a specific scenario class: FR-01, FR-02 and FR-03 (igneous intrusive and seismic GMD 10K yrs old method) FR_MC-01, FR_MC-02 and FR_MC-03 (seismic GMD 1M yrs), FR_SE-01, FR_SE-02 and FR_SE-03 (seismic GMD 10K yrs –

new method), FR_MCT-01, FR_MCT-02 and FR_MCT-03 (igneous eruptive), FR_FD-01, FR_FD-02 and FR_FD-03 (seismic Fault Displacement), FR_CV-01, FR_CV-02 and FR_CV-03 (early failure).

4. The calculation is launched by pressing the button "launch calculation". The appropriate info files are created. The appropriate DLL is called.

5. The calculation ends.

Besides the main GUI routine, the code is composed of several DLLs. One DLL is dedicated for the splitting of Goldsim files (Exdoc_la_tr.dll). All the other DLLs calculate expected values and CCDF at a specified time.

All DLLs consist of a main subroutine and one or more of the following subroutines:

- **SHELL_SORT** - This subroutine sorts an array of real. Its parameters are:

- SAMPLE_SIZE: an integer indicating the size of the array
- SAMPLE_IN: a one-dimensional array of real containing the unsorted data
- SAMPLE_OUT: a one-dimensional array of real designed to contain the sorted data.
It is called by the code to sort the expected dose in order to calculate quantiles. It is also used on the CCDF to calculate the same statistics. The sorting method used is the shell sort, described in *Numerical Recipes in Fortran 77, The Art of Scientific Computing* (Press et al. 1992 [DIRS 103316]).
Note that the sorting technique is used in the main code on bi-dimensional arrays. One of the dimensions is fixed when the subroutine is called (the data is sorted at each timestep so the time is fixed and the sorting technique is applied on the sample size).

- **SHELL_SORT_2D** This subroutine sorts a two-dimensional array of real. Its parameters are:
- SAMPLE_SIZE: an integer indicating the size of the first dimension of the array

- SAMPLE_IN: a two-dimensional array of real containing the unsorted data (the second dimension is composed only of two elements)

- SAMPLE_OUT: a two-dimensional array of real designed to contain the sorted data (the second dimension is composed only of two elements).

Each array can be considered as two vectors. The sorting technique has been extended to reorganize the data of the two vectors at the same time by sorting the first vector.

- **INTEGRATION_AMPLI** - This subroutine calculates the two integrals needed for integrating along the amplitude of the events for the seismic GMD case (10K years), and seismic FD case. This calculation can be done at the beginning of the code, since they are only dependent on the amplitude.

Note that the subroutine is called inside a loop based on the amplitude values for which the dose has been calculated (boundaries of the calculated integral).
Its parameters are:

- NB_AMPLITUDE: integer representing the discretization level used for calculating the integral

- NB_LAW_A1: integer representing the dimension of the law_amplitude array

- LAW_AMPLITUDE: bi-dimensional array containing the frequency law of the amplitude of the event (as a CDF)

- LOW_AMPLI: lower boundary of the integral

- HIGH_AMPLI: upper boundary of the integral

- AMPLI_INTEGRALS: mono-dimensional array (two parameters) designed to contain the two integrals used.

- **LINEAR_INTERPOLATION** This subroutine performs a classical linear interpolation of a value y=f(x) with $x\_l < x < x\_r$, knowing $y\_l = f(x\_l)$ and $y\_r = f(x\_r)$. Its parameters are:

- LEFT_X: a real corresponding to the left boundary value for x

- RIGHT_X: a real corresponding to the right boundary value for x

- VALUE: a real corresponding to the x value for which one wants to know the y value

- LEFT_Y: a real corresponding to the value of y associated to LEFT_X

- RIGHT_Y: a real corresponding to the value of y associated to RIGHT_X

- INTERP_VALUE: result of the interpolation