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Development of seismic database management tool

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Summary

In order to have a clear, exact and unified expression of each component's seismic failure probability, a dedicated opensource database standalone tool, has been developed. The Seismic PSA DataBase tool (SPSADB) allows for the implementation of any mathematical expression to define seismic basic event (BE) failure probability including shared parameters between different BE probability. With a clear and intuitive interface (no line code writing), it allows for expressing each BE seismic failure probability as a function of laws (lognormal, etc.) and parameters, that may be shared between several BE, to fit these laws. This tool is also able to compute the data base to define either a single set of seismic BE probabilities for a given seismic level, or Mont Carlo generated seismic sets of BE probabilities with a complete and correct integration of all possible correlations. It has to be noted that, here, the notion of "complete and correct correlation" refers to the correlation among different components potentially located at different elevation in a building. This is the user responsibility to define the appropriate level of correlation that as to be define in the tool for identical components located at the same place. The present document is the user manual of SPSADB tool.

Approval

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METIS

Seismic Risk Assessment
for Nuclear Safety

Research & Innovation Action

NFRP-2019-2020

Seismic PSA Database tool - User Manual

Deliverable D7.2

Version N°0

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Abbreviations and Acronyms

Acronym	Description
BE	Basic Event
CDF	Core Damage Frequency
EPRI	Electric Power Research Institute
MCS	Minimal Cut Set
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Assessment
PSHA	probabilistic seismic hazard analysis
SPSA	Seismic PSA
SPSADB	Seismic PSA DataBase tool

Summary

In order to have a clear, exact and unified expression of each component's seismic failure probability, a dedicated opensource database standalone tool, has been developed.

The Seismic PSA DataBase tool (SPSADB) allows for the implementation of any mathematical expression to define seismic basic event (BE) failure probability including shared parameters between different BE probability. With a clear and intuitive interface (no line code writing), it allows for expressing each BE seismic failure probability as a function of laws (lognormal, etc.) and parameters, that may be shared between several BE, to fit these laws. This tool is also able to compute the data base to define either a single set of seismic BE probabilities for a given seismic level, or Mont Carlo generated seismic sets of BE probabilities with a complete and correct integration of all possible correlations. It has to be noted that, here, the notion of "complete and correct correlation" refers to the correlation among different components potentially located at different elevation in a building. This is the user responsibility to define the appropriate level of correlation that as to be define in the tool for identical components located at the same place.

The present document is the user manual of SPSADB tool.

Keywords

Database ; fragility ; correlation ; probability ; uncertainty

1 Introduction

1.1 Purpose of this tool

The Seismic PSA DataBase tool (SPSADB) has been designed to perfectly handle the different level of correlation (partial and full correlation) between basic events when quantifying a Seismic PSA (SPAS).

For example, when the EPRI approach is used, the probability of failure, for a given component, is defined based on mathematical laws which use inputs like:

- the probabilistic seismic hazard analysis (PSHA) which is shared by all components,
- the floor spectral responses of the different levels of each building, which can be shared between several components located on the same floor of a given building,
- some assumptions about the representativeness of the qualification test performed or about the finite element modelling, for example, which can be shared between many components,
- …

All these shared inputs / parameters introduce partial correlation between basic events probability which can be expressed through mathematical laws.

The purpose of SPSADB tool is to allow to express these mathematical laws with shared parameters to generate a sample of basic event failure probability which takes perfectly into account the correlation (partial or total) among seismically induced failure. By this way, thanks to SPSADB tool, there is no loss of information (especially about correlation) due to the adaptation of the method to the PSA tool.

Note: the notion of "correlation" refers to the correlation among different components potentially located at different elevation in a building. These correlations are due to shared assumption or shared uncertainties, for example due to concrete dumping value considered.
This is the user responsibility to define the appropriate level of correlation that must be define in the tool for identical components located at the same location. The definition of these correlations is a methodological issue rather than a tool issue. However, due to its flexibility, the SPSADB tool allows to define any level of correlation among identical component at the same location once the methodology is defined.

1.2 Principle of SPSADB Tool

The principle of this tool is to allow the user to declare all the parameters used to fit the different mathematical laws used to define the seismically induced probability of each basic event of the SPSA. These parameters are named "parent" or "upstream" parameters and can be shared by several basic event probability definitions. Each upstream parameter can be:

- a fixed value,
- a random and independent value (defined by a distribution law),
- a value based on upstream parameters (i.e. defined from "grandparents" parameters through mathematical laws).

The user defines also "parameters" that correspond to the seismic failure probability of each component modelled in the PSA. These are named "children" parameters or "final" parameters. They are the purpose of the tool and the ones transmitted to the PSA to re-quantify the MCS set.

Once all the final parameters and all upstream parameters (shared or not) are defined and linked together through mathematical laws, it is possible to generate a sample of perfectly correlated[1] basic

[1] The "perfection" comes from the fact that all the level of partial correlation expressed through mathematical laws are correctly implemented in the data base.

events. The partial correlation of basic events probabilities comes from the fact that some shared upstream parameters are used. For each monte Carlo run, these upstream parameters have a unique value which is repercussed to all their children basic event's probability parameters. No simplification is done between the mathematical expression defined in the EPRI approach, for example, and the values used in the PSA. Thus, the SPSADB tool can be used either to:

- assess the level of uncertainty for a given level of PGA (free field),
- have a continuous estimation (with uncertainties) of the core damage frequency (CDF) as a function of the PGA,
- perform sensitivity studies on user defined parameters based, for example, on engineering judgement,
- …

During a Monte Carlo generation of a sample, at step one, a value is defined for all the unliked parameters (which are defined with an unlinked distribution or a fixed value). Then, during step two, these upstream parameters' values are used to generate the values of their downstream parameters. If these downstream parameters are also the parents for other parameters, an additional step is done to update these children. For each run, this process is repeated until all parameters' values are defined.

By this way, a final parameter can be defined through any number of layer of parameters shared or not to represent the partial correlation among components' seismically induced probability of failure.

2 Presentation of the interfaces

The SPSADB is developed with Excel macro. To launch it, you just have to open the corresponding Excel folder. You need, first, to authorise excel to execute macros.

There is two levels of utilisation of the tool:

- the standard level allows to declare new parameters and to modify existing ones. It also allows to define the parameter's value definition (law, fixed value…) and to modify complement the list of parameter's types,
- the developer level allows also to define new laws to express the parameters' value (based on upstream parameters or not). This mode is protected by a password and is detailed in §3 page 12.

2.1 Generalities

A parameter defined in the SPSADB tool always have:

- a unique name (it is not possible to have two parameters with the same name);
- a parameter's description that helps to identify the meaning of this parameter;
- a parameter's type used to have a readable database;
- the source of the value which can be:
    - a law based on upstream parameter or
    - an unliked value either defined by a law expressed with numerical values or a fixed numerical value;
- the type of the law (if any);
- the fixed value which is always used or which is used as a substitution of the law (see bellow) for some specific studies like sensitivity studies;

- a Boolean which indicates if the fixed value is used or if the law is applied to define the parameter's value;
- if the parameter's value is defined through a law, either the upstream parameter(s) used to fit the law or, in case of an unliked parameter, the numeric values used to fit the law are defined;
- if the parameters value has to be generated in the output file (say yes only for final parameters which correspond to basic events seismic failure probabilities).

2.2 List of parameters

The pages "List of parameters" and "Filtered list of parameters" (see Figure 1 and Figure 2) are similar. They present the list of parameters defined in the database and, once a parameter is selected, they offer the possibility to:

- delete it,
- modify it (see §2.3 page 4).

It is also possible to create a new parameter. It is then defined in the page "Specification of the selected parameter" (see §2.3 page 9).

When the user double clicks on a parameter, its definition is shown (without the possibility to modify it).

In the page "Filtered list of parameters", it is possible to filter the parameters based on their name, their type and their description. Wild chars "*" and "?" can be used. The parameters shown always corresponds to all the filters. Thus, for example, if you don't want to filter based on parameter's name, you need to put "*" in the text box "Parameter's name" (see Figure 2).

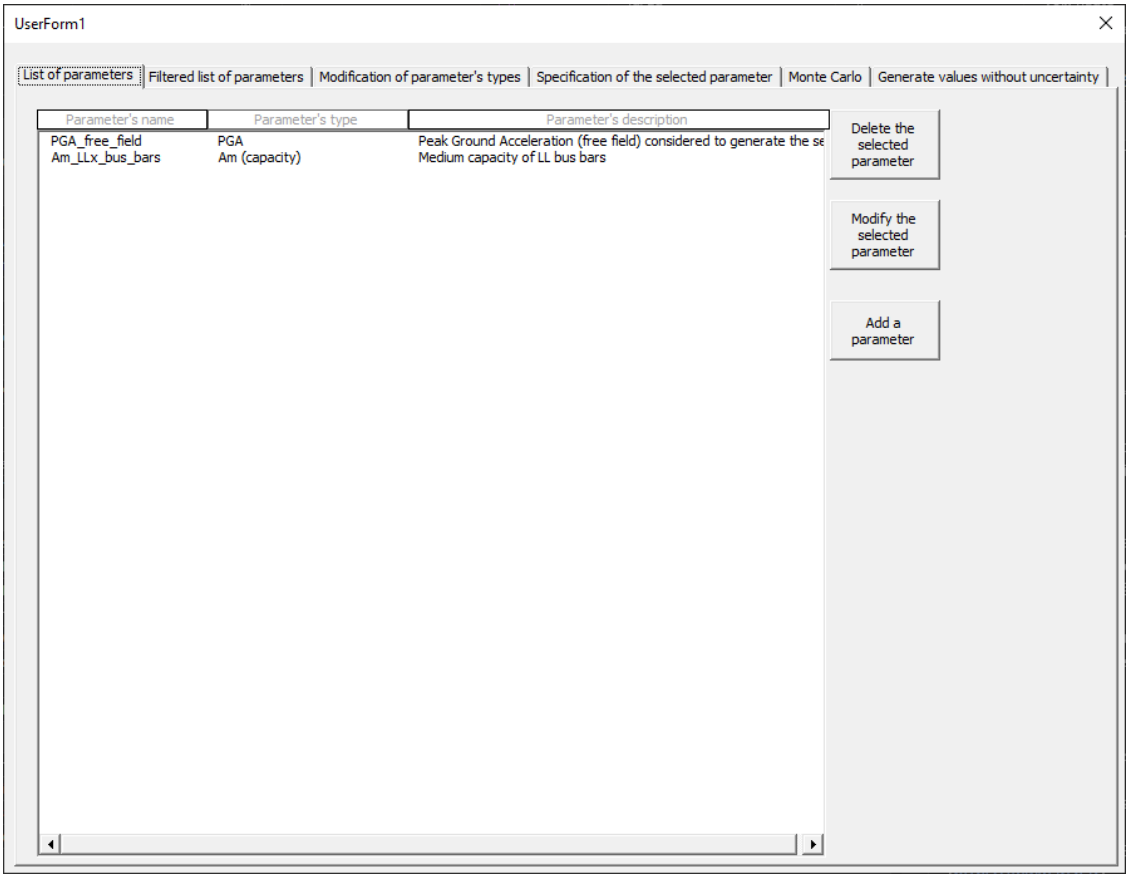


Figure 1: screen capture of the page "List of parameters"

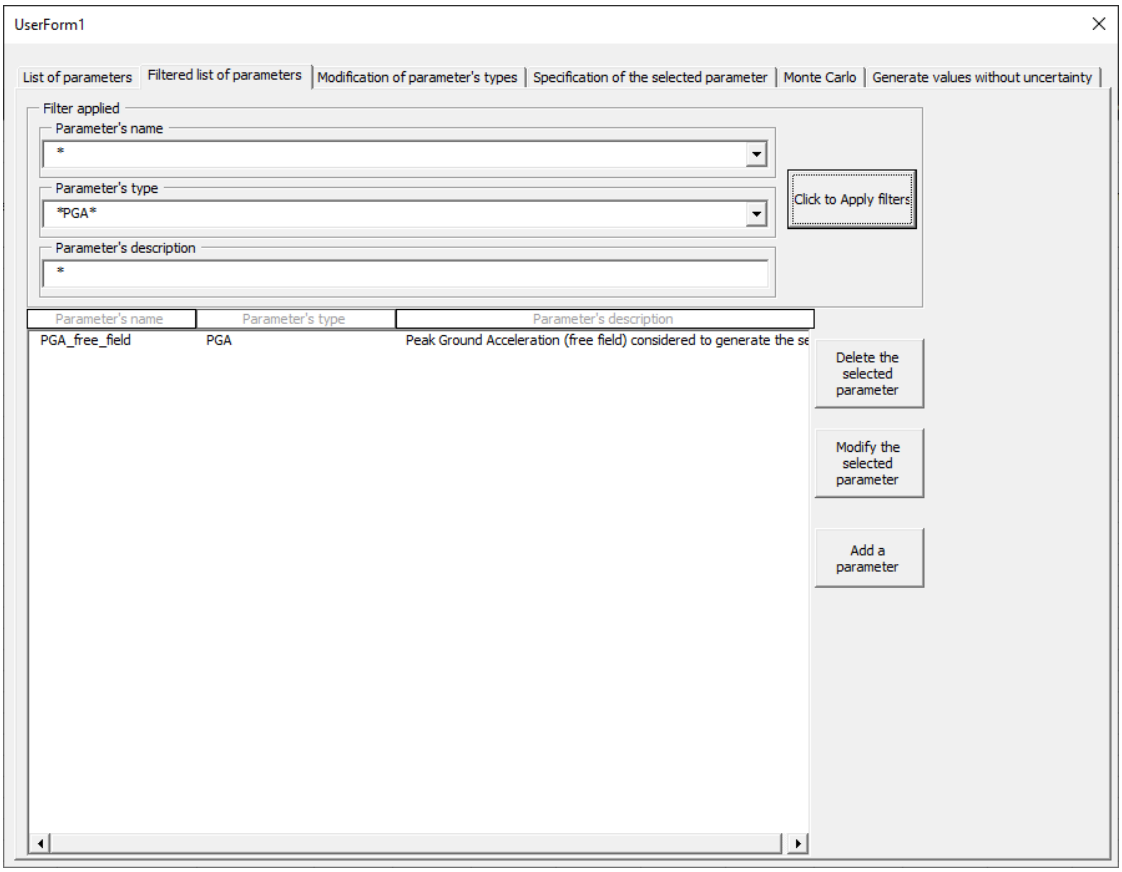


Figure 2: screen capture of the page "Filtered list of parameters"

2.3 Modification of a parameter's definition

To understand the vocabulary bellow it is preferable to read §2.1 page 7.

With the page "Specification of the selected parameter" it is possible to define:

- the parameter's name,
- the parameter's type,
- the parameter's description,
- the source of parameter's value (linked or unliked law),
- the law name (the laws are defined with the developer mode, see §3 page 12),
- the fixed value,
- if the fixed value is used or not through the toggle button "use fixed value" / "use law/matrix value",
- if this parameter's values has to be included in the output file during Monte Carlo sample generation,
- it is possible to modify the values of the "parameters" used to fit the law through the button "Modify the related parameter". These "parameters" can be either numeric values or upstream parameters.

The definition of a law is performed through a dedicated interface (see Figure 4) where the user has to select an upstream parameter or to define a numeric value and then to press the button "Validate the value" to validate this change. Any parameter of the law can be modified. To do it, click on it and change the value.

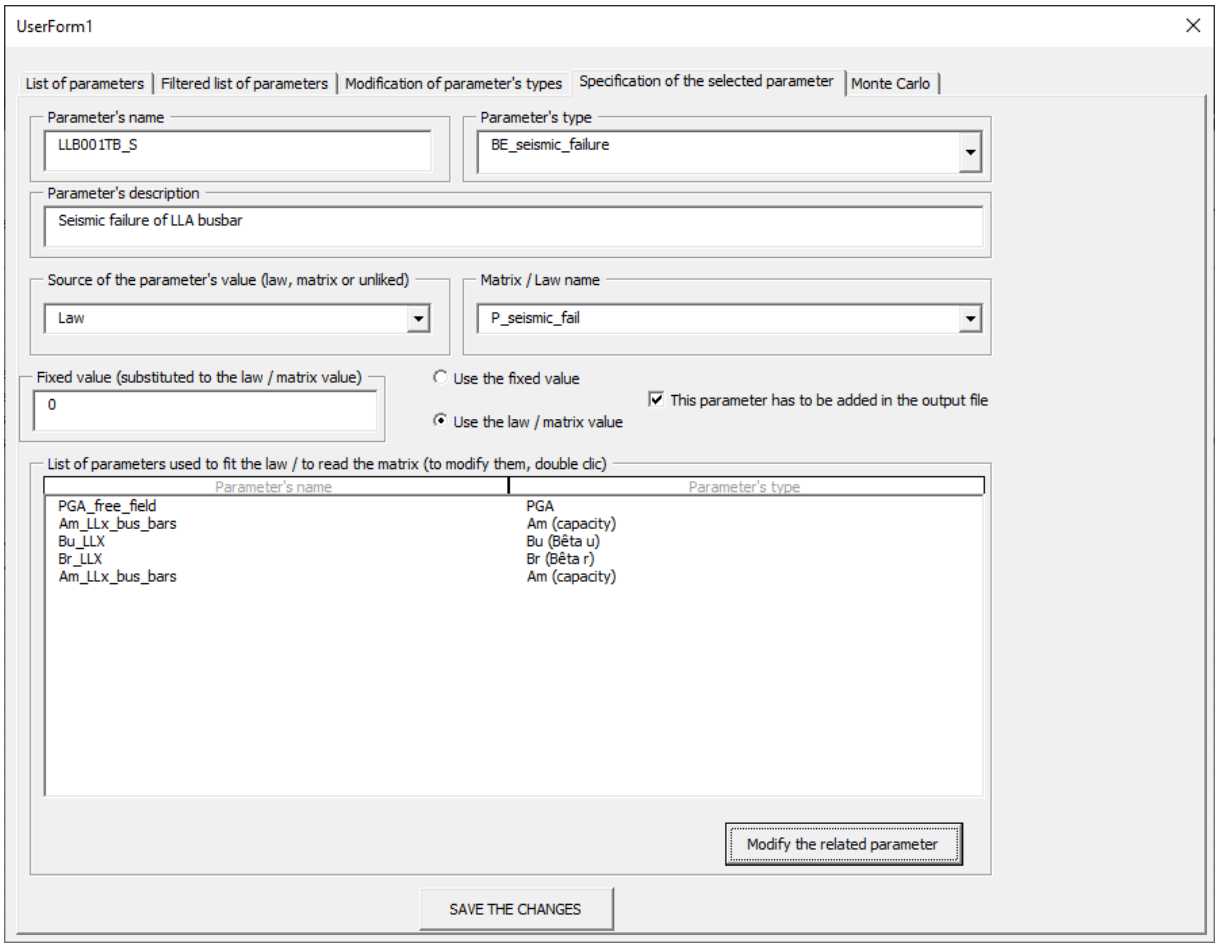


Figure 3: screen capture of the page "List of parameters"

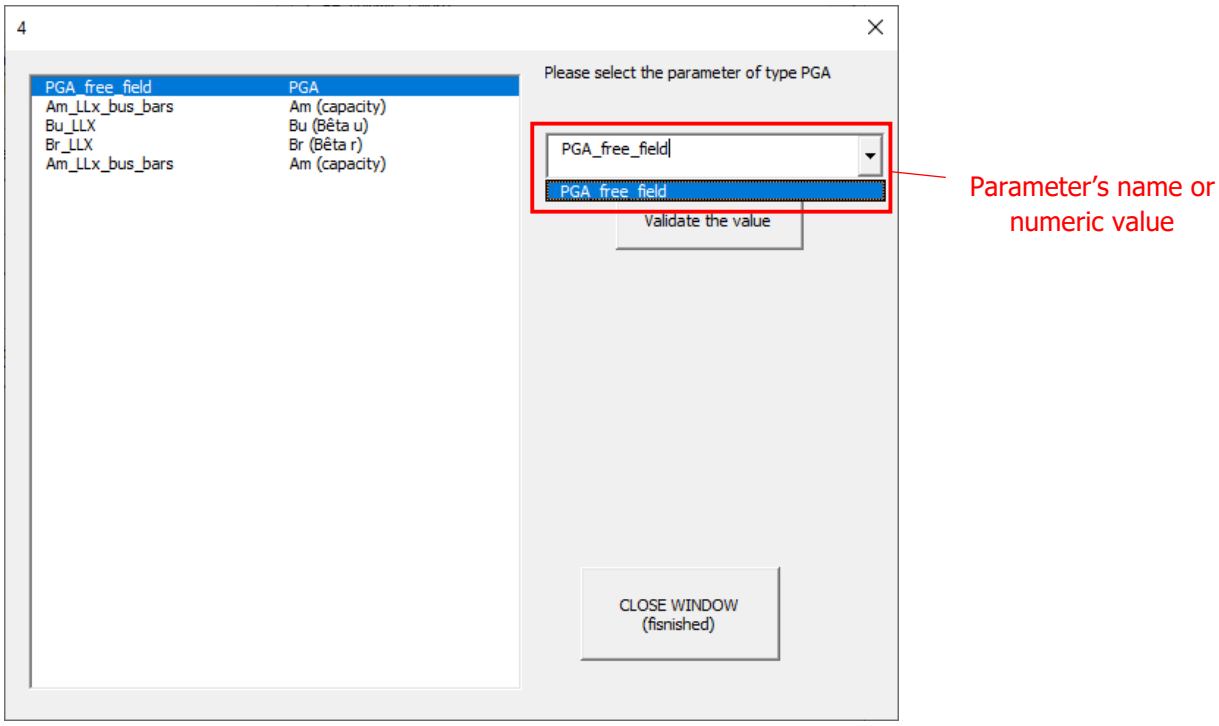


Figure 4: screen capture of the interface used to define the parameters of the law used to define a parameter's probability

2.4 Launch a Monte Carlo sample generation

To launch a Monte Carlo sample generation, it is required to define:

- the size of the sample (for example, 1000 on Figure 5),
- the location of the file containing the sample. To define this location double click on the white text box "Localisation of the file(s)…".

and to click on the "Launch…" button.

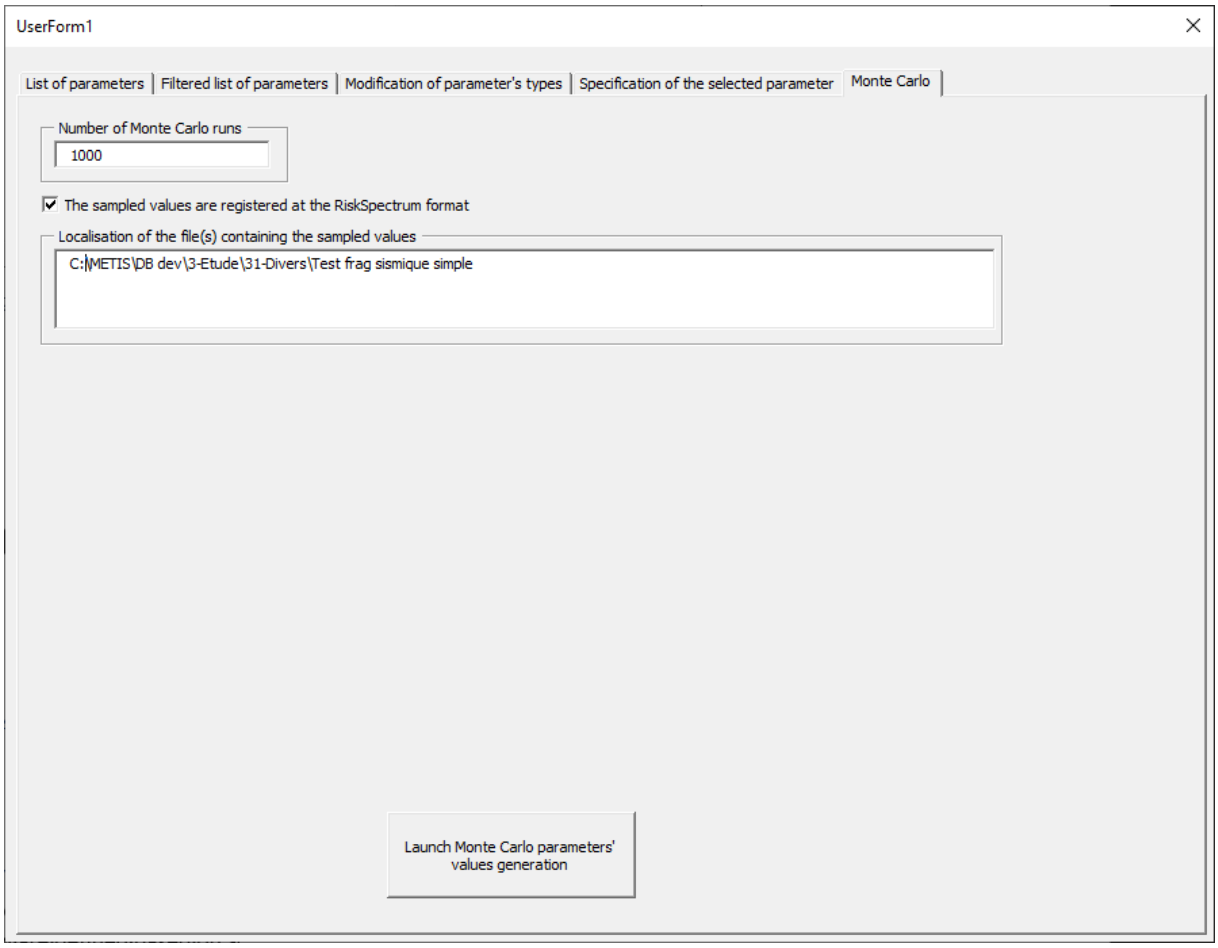


Figure 5: screen capture of the interface used to generate a Monte Carlo Sample

3 Developer mode

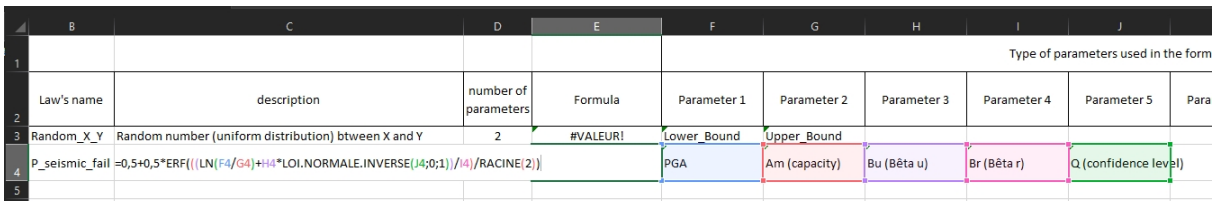
In developer mode it is possible to declare new laws used to define some parameter's values. These laws are defined based on:

- their name (which must be unique),
- their description,
- the number of parameters used to fit them,
- the formula used to define the law. This formula has to refers only to the cells located on its right at the same line: i.e. to the fitting parameters list. Any combination of mathematical laws implemented in Excel can be used.

Law's name	description	number of parameters	Formula	Parameter 1	Parameter 2	Para
Random_X_Y	Random number (uniform distribution) btween X and Y	2	#VALEUR!	Lower_Bound	Upper_Bound	
P_seismic_fail	Seismic probability of failure, EPRI approach, as a function of acceleration (a), Am, Bu, Br and Q (confidence level)	5	#VALEUR!	PGA	Am (capacity)	Bu (Bêt

Since these law definitions are performed only by expert users there is a limited number of coherence test implemented. You have to be careful when defining a law:

- to be consistent between the number of parameters declared and the real number of parameters used,
- to use only the parameters from the same line declared from column "F" as shown in example bellow.



	B	C	D	E	F	G	H	I	J	
1					Type of parameters used in the form					
2	Law's name	description	number of parameters	Formula	Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5	Para
3	Random_X_Y	Random number (uniform distribution) btween X and Y	2	#VALEUR!	Lower_Bound	Upper_Bound				
4	P_seismic_fail	=0,5+0,5*ERF((LN(F4/G4)+H4*LOI.NORMALE.INVERSE(J4;0;1))/I4)/RACINE(2))			PGA	Am (capacity)	Bu (Bêta u)	Br (Bêta r)	Q (confidence level)	
5										