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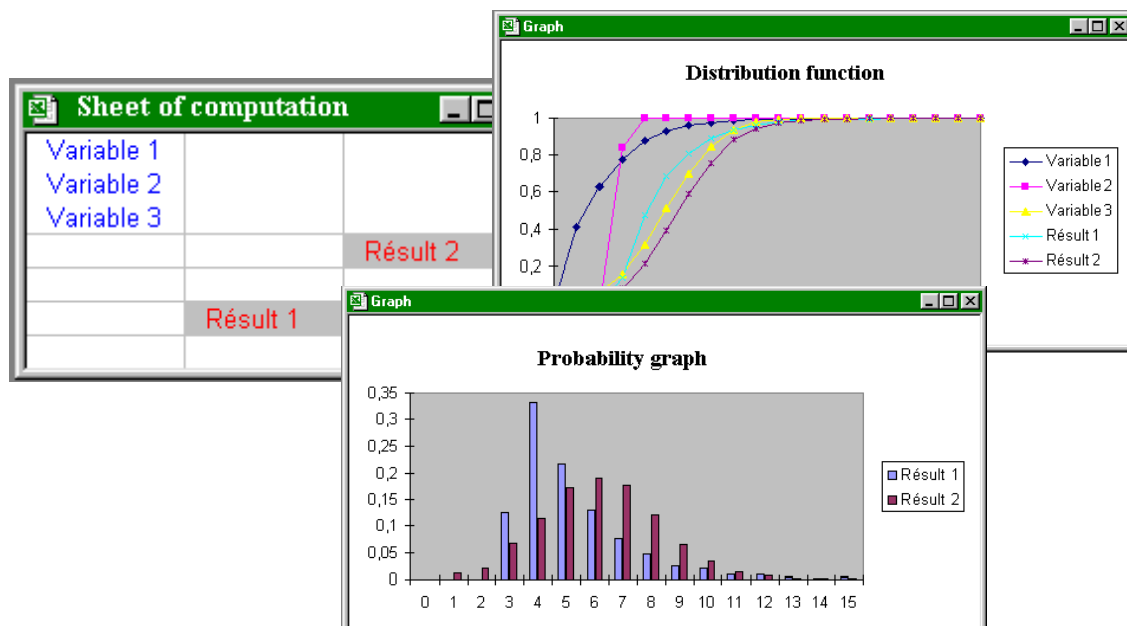
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SIMCAB Version 13

using Microsoft EXCEL®



Generic Monte-Carlo Simulation Tool

User's Manual

FOREWORD

The software *SIMCAB BASIC* version 6 includes some of the *SIMCAB* version 13 features. It is not the subject of a specific user manual.

The copyright law and international conventions protect the *SIMCAB* software and its User's Manual. Their reproduction or distribution, either wholly or partly, through any means whatsoever, is strictly prohibited. Any person who does not comply with such provisions is committing an offence of forgery and is liable to prosecution and can be sentenced under the provisions prescribed by the law.

The Programming Protection Agency (A.P.P.) references *SIMCAB* at the I.D.D.N. (Inter Deposit Digital Number) index, with the following reference:

IDDN.FR.001.460001.00.R.P.2000.000.20700

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OPERATING LICENCE AGREEMENT

1 *SIMCAB* Software

1.1 General Presentation

SIMCAB is a generic Monte-Carlo simulation program which helps supplementing spreadsheet with random variables so as to enable any user to control dispersions in computations or efficiently simulate varied problems.

Using a menu offered by program, the user defines the names and features of random variables used in his computation and designates sheet cells containing results. So, he may initiate simulation, then display the graph results (frequency graph, probability graph, distribution function ...) and, using them, perform various statistic processings (average, median, typical deviation, kurtosis, asymmetry, confidence interval, correlation, ...).

Many probability laws are offered by the program (Beta, Binomial, Erlang, Exponential, Gamma, Geometric, Gumbel, Hypergeometric, Lognormal, Normal, Pareto, Pearson, Personalized, Poisson, Triangular, Uniform, Weibull...) which can be adjusted by the program from experimental data (using maximum-likelihood method).

SIMCAB allows processing recursive simulation models in order to assess dynamic and hybrid systems (with continuous and discrete variables).

A function of simulation of Markovian systems is also proposed by the tool.

In addition, *SIMCAB* can be jointly used with the other tools of *CAB INNOVATION*, either to control scattering in assessments performed by the software of Reliability *SUPERCAB* and *CABTREE*, or to achieve optimizations by means of tool *GENCAB* starting from the simulation results.

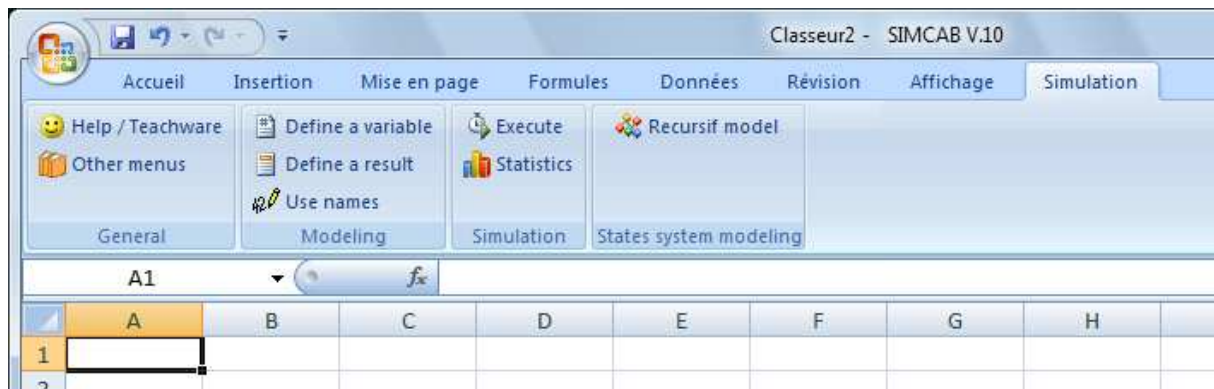
1.2 Installing *SIMCAB* on Hard Disk

Please follow instructions shown in manual.

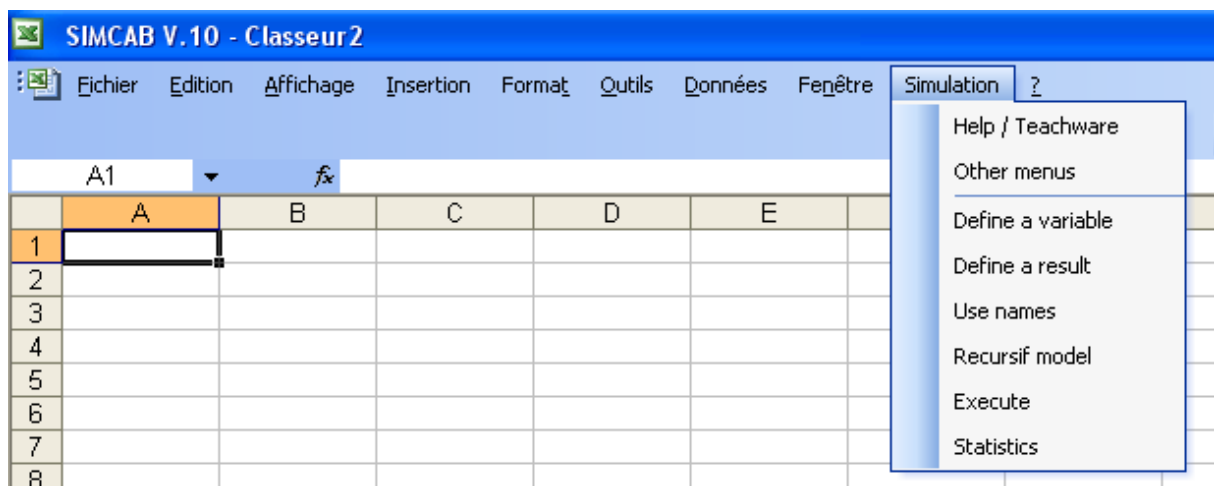
1.3 Starting *SIMCAB*

In EXCEL, open *SIMCAB.XLA* file.

Software's functionalities are then accessible using menu "Simulation", spreadsheet functionalities remaining always available.



Banner on Excel versions after 2007



Menu on Excel versions prior to 2007

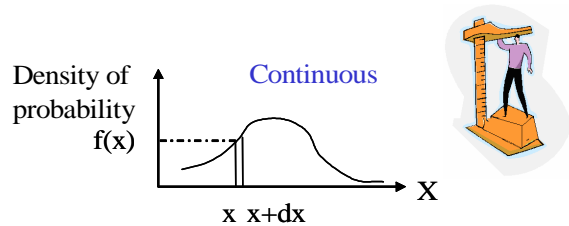
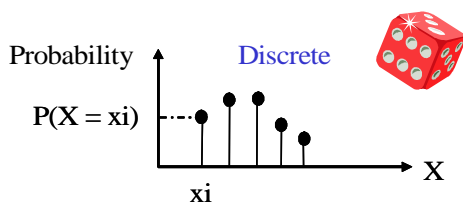
Teachware and help are proposed in menu with many examples of application.

2 Teachware

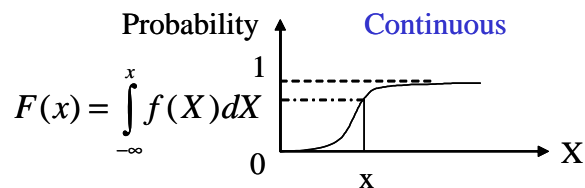
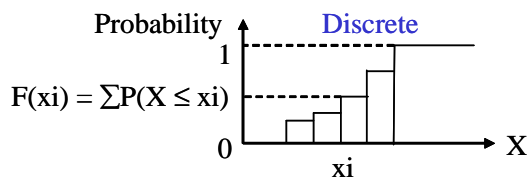
The teachware presents the bases of the simulation of Monte Carlo by means of various figures and demonstrations.

2.1 Recall on the statistics

A random variable X is a variable resulting from a random phenomenon which admits a measurement of probability. It can be discrete (value obtained during a pulling of dice) or continuous (size of a population).

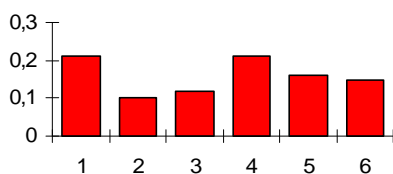


Each possible value of a discrete variable can be characterized by a probability value ($p = 1/6$ for the 6 faces of the dice). Each possible value of a continuous variable can be characterized by a density value of probability $f(x)$ such as the probability that the random variable X ranging between x and $x+dx$ is equal to $f(x)*dx$ when $dx \rightarrow 0$ (surface under the curve). The function of distribution corresponds to the probability that the random variable X is lower than a value X .

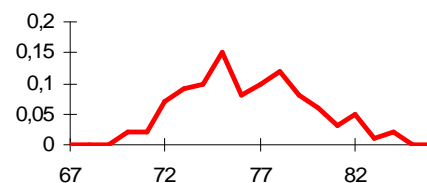


Demonstration: pulling of dice and measurement of the size of individuals (100 values):

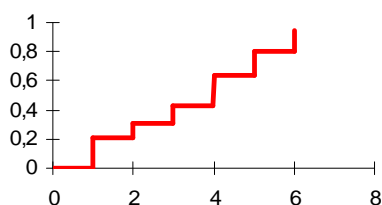
Graph of probability



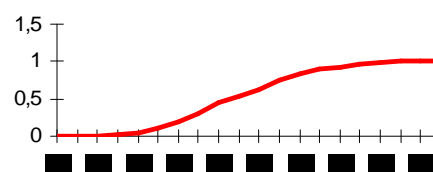
Density of probability



Function of distribution



Function of distribution



Average : 3.48
Standard deviation: 1.73

Average : 75.87
Standard deviation: 3.19

2.2 Choice and adjustment of probability laws

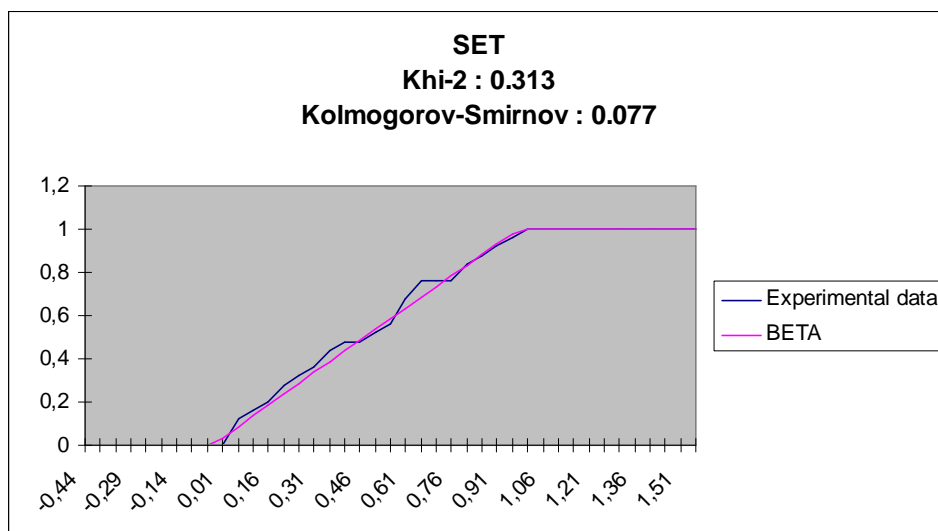
A law of probability makes it possible to model a random variable. To choose a law of probability as well as possible we proceed in the following way:

- 1 - Analyze the nature of the parameter (discrete or continuous) and its physical significance
- 2 - Seek experimental data possibly censored (sample, operational data, test results, judgement of expert...)
- 3 - Choose a law corresponding to the physical phenomenon, if it exists, or being able to represent the experimental data
- 4 - Carry out an adjustment to find the parameters of the law corresponding as well as possible to the experimental data

The maximum-likelihood method is used by the tool for adjustment. It consists in maximizing the product of the probability densities of the law considered for the values of the experimental data. This product is multiplied by the probability of non-occurrence for the censored data,

The quality of the adjustment carried out can be evaluated by various statistical tests (Khi-2, Kolmogorov-Smirnov...). Those give a measurement of the difference between the function of distribution of the law considered and that of the experimental data.

Demonstration: Adjustment of various laws of probability starting from randomly values:



2.3 Principle of the Monte-Carlo simulation

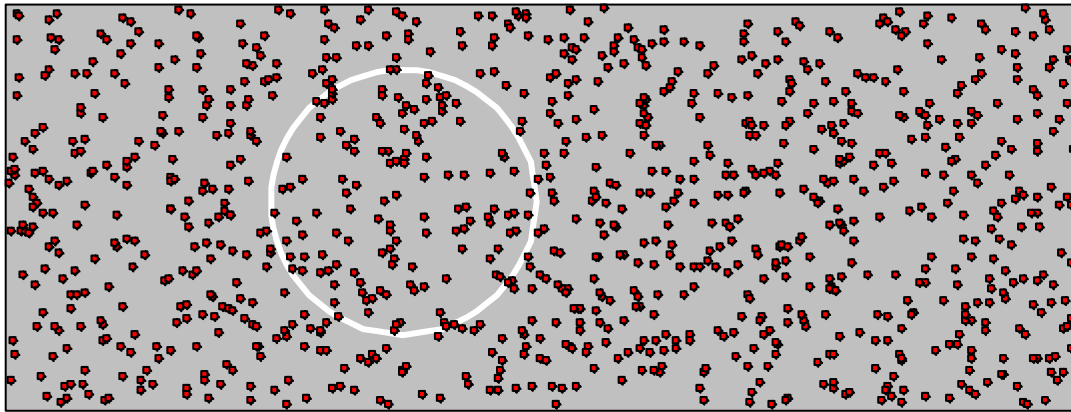
Monte-Carlo simulation is a method of calculation based on random pulling

Demonstration: How to measure the surface of a figure drawn on the blackboard whose surface is known?

- 1 - Organize a chalk brawl in the classroom
- 2 - Count the chalk impacts on the figure and on the whole of blackboard
- 3 - Multiply the surface of the blackboard by the relationship between the first value and the second

The precision of calculation will be of as much better than the brawl will be long and the participants bad sights.

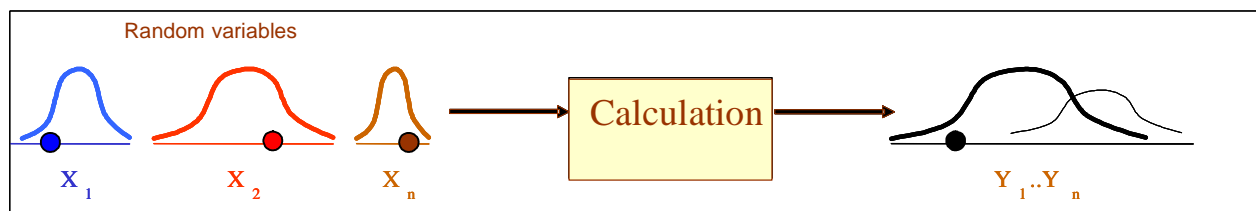
Surface of the blackboard: $4 \text{ m} * 1,5 \text{ m} = 6 \text{ m}^2$ Surface of the circle: $\Pi * 0,5^2 = 0,785 \text{ m}^2$



127 impacts in the target on 1000. The surface of the figure is: $6 * 127 / 1000 = 0.762 \text{ m}^2$
The value of Π is approximately: 3,048

2.4 Control uncertainties by Monte-Carlo simulation

Monte Carlo simulation allows evaluating uncertainties in a calculation while proceeding in the following way:

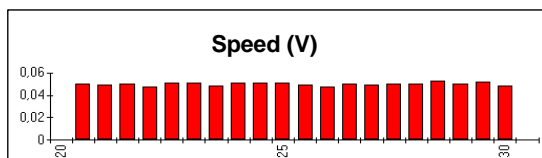
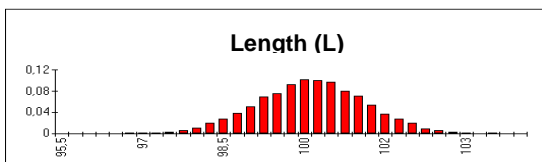
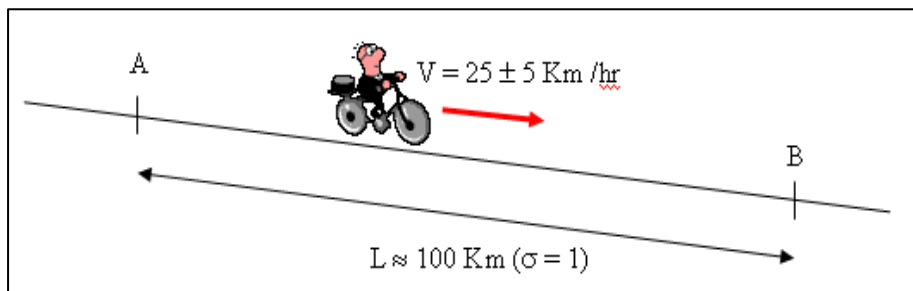


- 1 - Make a random drawing of the entries in accordance with their statistical distribution
- 2 - Inject the values of these entries in calculation in order to obtain a result
- 3 - Reiterate the operation a great number of times in order to obtain a distribution of result

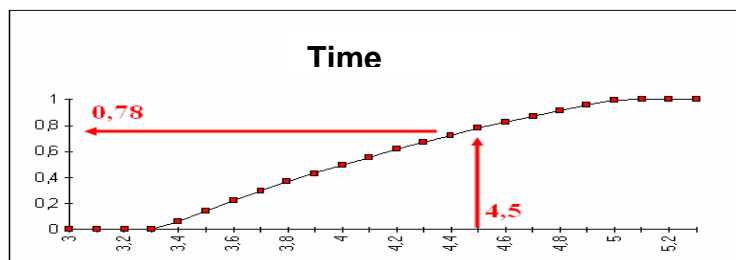
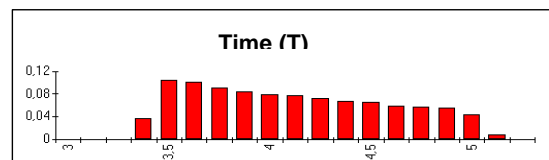
Easy to implement the simulation of Monte-Carlo allows carrying out analyses of uncertainty or sensitivity. It guarantees the covering of the worst cases which are not always easy to identify.

Statistical distribution is much richer than a simple average value because it makes it possible to calculate the probability that the result is included in an interval.

Demonstration: Uncertainty over the duration of a way



$$T = L / V$$

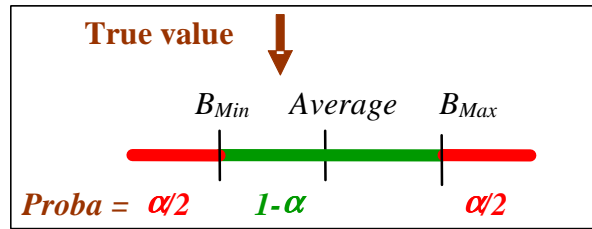


The probability that the journey time is lower than 4 hours 30 is 0.78.

The function of distribution, obtained by simulation, makes it possible to evaluate the probability that the result is lower than a certain value or included in an interval.

2.5 Concept of confidence interval

The confidence interval makes it possible to evaluate the "true" value of a parameter on the basis of result of simulation or observations carried out on a sample. The confidence interval at the α risk contains the value of the parameter with probability $1 - \alpha$.

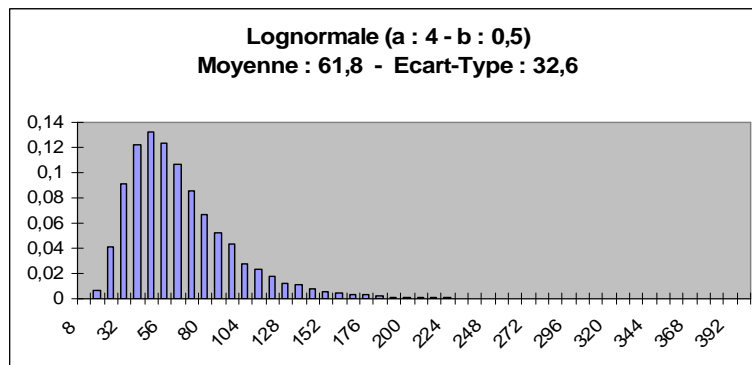


Defined by the central limit theorem, it is all the more narrow as the variance (standard deviation) is weak and that the size NR of the sample (a number of simulations) is large.

$$m \pm U_{\alpha/2} \frac{\sigma}{\sqrt{N}} \quad \text{or} \quad A \pm U_{\alpha/2} \sqrt{\frac{A(1-A)}{N}}$$

in the case of a proportion with $U_{\alpha/2} = u(1-\alpha/2)$ the reverse of the function of distribution of the reduced centered normal law.

Demonstration: Evaluation of the average of a Lognormale law



61,8678093 \downarrow $= e^{(a + \frac{1}{2}b^2)}$ N = 1000 m = 61.77 sigma =

$\alpha = 40\%$ _____

$\alpha = 10\%$ _____

Confidence intervals at 60 and 90%

2.6 Quantile

A quantile is the value that separates the data distribution in a certain proportion.

Quantile function is the inverse of the distribution function.

Quantiles from 1 to 99 (%) are called percentiles.

Quantiles 10 to 90 are called deciles.

Quantiles 25, 50 and 75 are called quartiles.

The 50 percentile is the median.

The quantile X is a variable value that the probability of passing through is X%.

Wilks method allows to estimate an upper bound (or lower bound) of a quantile α (%) with a confidence level β (%).

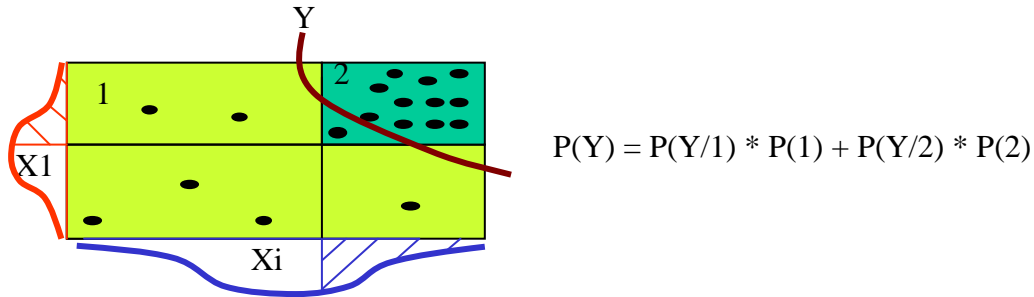
This value $Q_{\alpha/\beta}$ is equal to the data of rank r in size N sample defined by the Wilks formula:

$$1 - \sum_{N-r+1}^N C_n^i \alpha^i (1 - \alpha)^{N-i} \geq \beta$$

For example, the 95/95 quantile estimation of the temperature reached in a nuclear reactor in the absence of any cooling is used to size the ultimate barrier protection (tubes of graphite surrounding the uranium).

2.7 Methods of variance reduction

The reduction of variance consists in privileging a field of interest during simulation then to balance the results obtained by application of the theorem of the total probabilities.



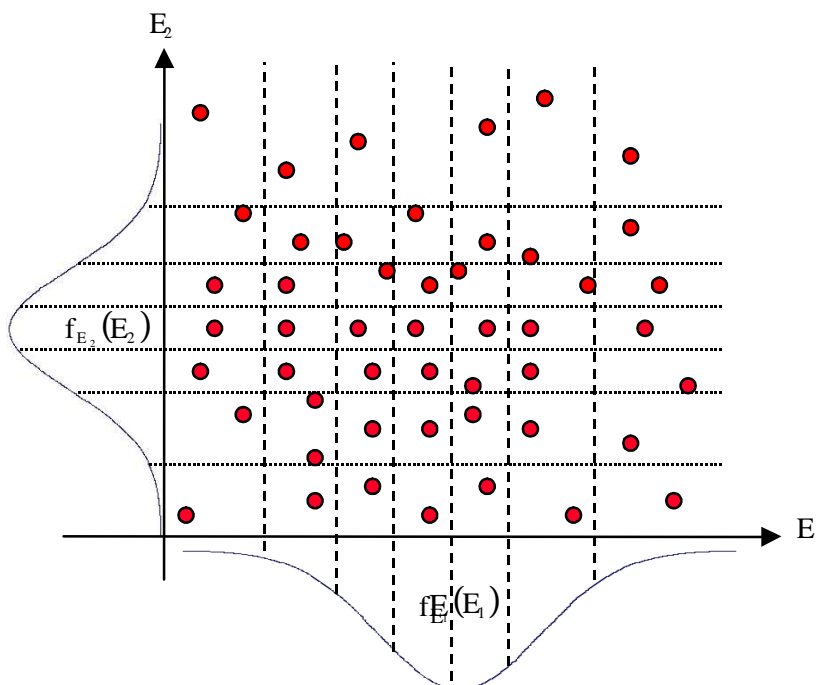
Objective:

- Increase the precision of the results (confidence intervals)
- Estimate the occurrence probabilities of rare events
- Decrease simulation duration

The reduction of the variance can be implemented by various methods:

Variance reduction per stratified sampling

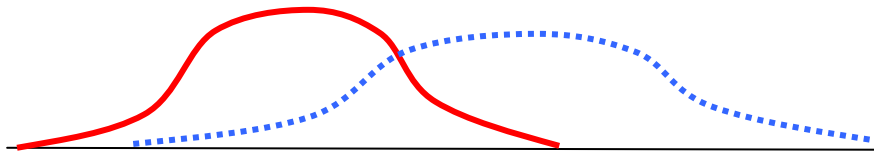
Creation of layers (squaring) disjoined on the entries and random pullings in each one of these layers. The estimate at exit is the sum of the estimates in each layer balanced by the probability that pulling of it results.



Pulling are carried out even in the least probable zones. The layers can be equiprobable (even probability), equidistant (even size) or personalized when we know the zone of interest to privilege.

Variance reduction per sampling of importance

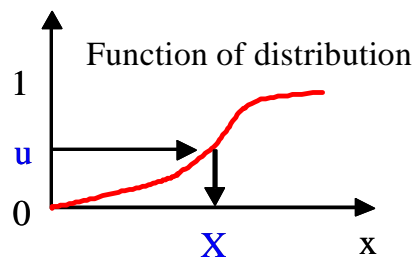
Use of a function of importance “to encourage” pullings in the interesting zones to reach



The weight which is given to each simulation is the ratio between the density of probability of the random function and that of the function of importance.

2.8 Simulation of random variable

Performed by the tool, the simulation of a random variable can be carried out in the following way:



- 1 - Draw a random values u between 0 and 1.
- 2 - Apply, from this value, the opposite function of the function of distribution, if it exists.
- 3 - In other cases, specific algorithms can be use.

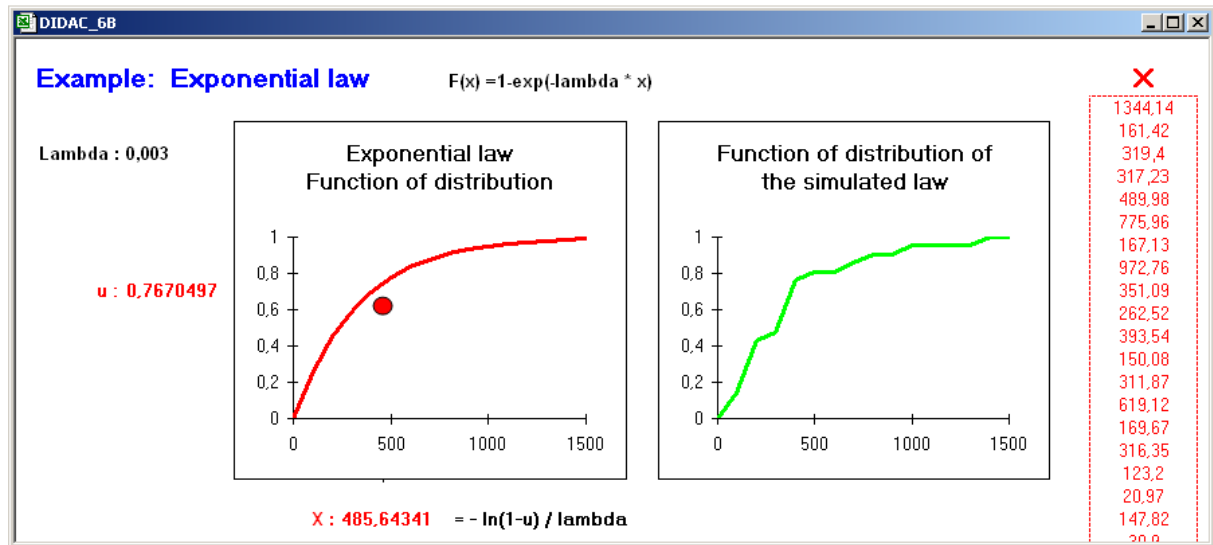
A random generator is an algorithm which allows creating lists of numbers uniformly distributed between 0 and 1. The numbers should not be correlated and the period of the list must be largest possible ($T_{\text{Simcab}} > 1\ 000\ 000$).

The tool proposes parametric random functions allowing simulating the following laws:

BETA, BINOMIAL, ERLANG, EXPONENTIAL, GAMMA, GEOMETRICAL, GUMBEL, HYPERGEOMETRIC, LOGNORMAL, NORMAL, PARETO, PEARSON, PERSONNALIZED, POISSON, TRIANGULAR, UNIFORM, WEIBULL with 2 or 3 parameters.

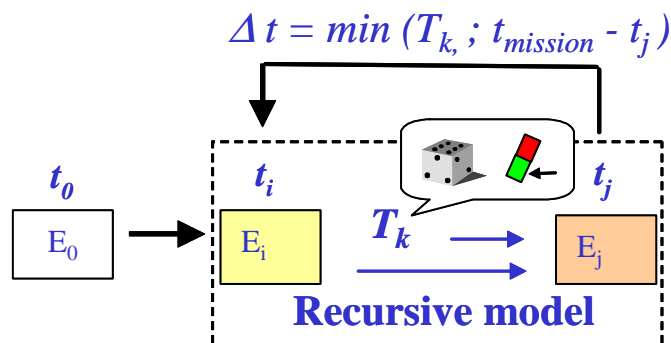
The format of these functions is: "L_EXP(,,,,)" with "EXP" the first 3 letters of the considered law.

Demonstration: Simulation of an exponential law



2.9 Model of recursive simulation

This is an original modeling technique of the discrete states systems :



The model of recursive simulation describes a generic transition from the states E_i (at t_i) to E_j (at t_j).

Its treatment consists in reinjecting in entry, the state at exit, starting from an initial state, as many time as it is necessary to cover the mission.

The increment Δt , from t_i to t_j , is the smallest computed value among various increments of time T_k .

These durations can correspond to deterministic or random changes of the system state (failure, repair...) or the crossing of thresholds by continuous variables in the case of the hybrid systems.

2.10 Simulator of system architecture

This tool can automatically generate a model of recursive simulation from a table filled in by the user.

Architecture

Passive Simulator
 Spare RBD

Equipment		Failure		Repair		Passive					Stock of spare				
N°	Name	Law	λ	Law	μ	Condition _{OFF}	Failure _{OFF}		T _{Reconf}		γ	N°	S	TAT	
							Law	λ_{OFF}	Law	T _{reconf}				Law	TAT
1		EXP		EXP			EXP		EXP					EXP	
2		EXP		EXP			EXP		EXP					EXP	
3		EXP		EXP			EXP		EXP					EXP	
4		EXP		EXP			EXP		EXP					EXP	
5		EXP		EXP			EXP		EXP					EXP	
+															

Operation		
N°	Name	Condition
1		
2		
3		
4		
+		

The table includes the characteristics of failure, repair, reconfiguration and logistic of the system components, and a logical description of nominal or degraded mode of operation.

The operating conditions and the conditions maintained in the passive state are defined using the operators AND (*) OR (+), NOT (~) and combination m among n : m/n(i + ... + k).

Given by default, the exponential can be replaced by other laws of probability (considering or not the Markov assumption).

The tool can also draw the Reliability Block Diagram (RBD) animated by the simulation (step by step) or as a picture.

3 Application

The user defines its processing on a calculation sheet using parameter names corresponding to random variables of which he specifies the features using menu "**Define a variable**".

Then, he designates sheet cells containing results using menu "**Define a result**".

Afterwards, he runs the simulation, using menu "**Execute**", then he displays the graph-shaped results.

He may achieve various statistical processing on results using menu "**Statistics**".

Menu "**Use names**", helps entering formulas in sheet's cells by using preliminarily-defined result or variable names, without having to enter them again.

Menu "**Define a variable**" helps also display different software-proposed probability laws, know their operating conditions using an online hotline, and perform settings on them from experimental data.

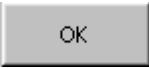

3.1 Defining a variable

Command "**Define a variable**" of menu "**Simulation**" allows to display dialog box below :

The dialog box titled "DEFINE A VARIABLE" contains the following elements:

- Used variables :** A list box with "Cost_per_unit" selected. Other items are "Launching_cost", "Number_of_sales", and "Price". A "Report" button is located to the left.
- Name :** A text box containing "Cost_per_unit".
- Type of law :** A text box containing "NORMAL".
- Probability Laws List :** A list box containing "BETA", "BINOMIAL", "ERLANG", "EXPONENTIAL", and "GAMMA". To its left are a "?" button, a "View" button, and a "Set" button.
- Average :** A text box containing "25".
- S. deviation :** A text box containing "2".
- Unit :** A text box containing "\$".
- Minimum :** A text box containing "0".
- Maximum :** A text box containing "100".
- Buttons :** "Add", "Delete", "OK", and "Cancel" are located at the bottom of the dialog.

3.1.1 Adding, Deleting, Displaying

Defining a variable consists in giving a name to it in box « Name » (Cost per unit in the example), choosing the relevant statistic law in a scrolling list (Normal), informing the value of law's parameters (Average : 25, Standard Deviation : 3) in relevant boxes which are displayed depending on law selected, then pressing button  or button  if a list of numerous variables is to be successively defined.


In order to simplify the entering, the parameters of the laws can be them even defined by parameters of the spreadsheet. Value 25 for example will be replaced by the name "Average" which itself will be given to a cell of the spreadsheet.


Minimum (0) and maximum (100) limiters for values likely to be assumed by variable as well as its unit (\$) may be also defined in relevant boxes.

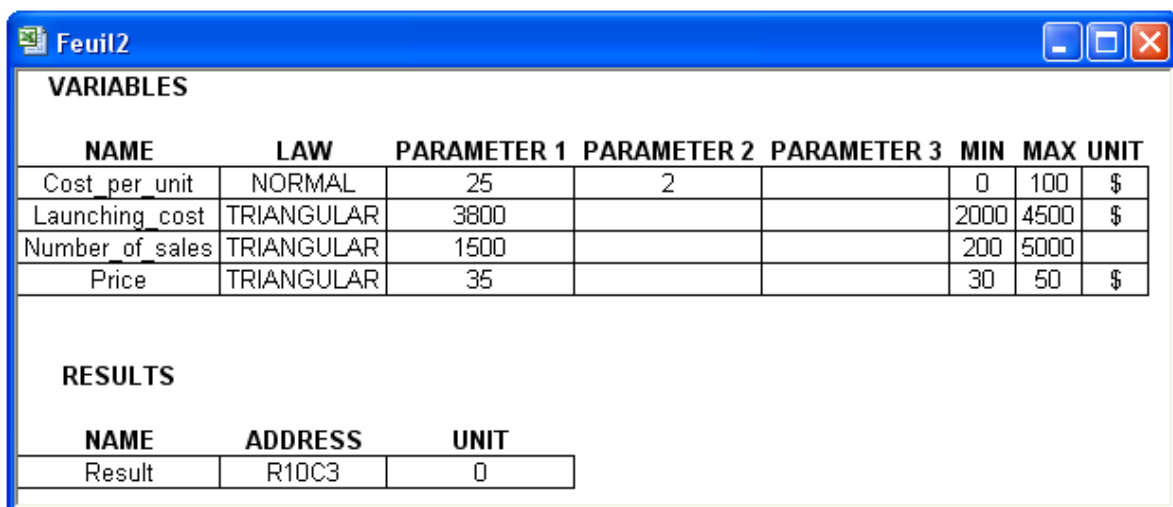
A name mentioned on sheet close to active cell is proposed by default as a variable name in dialog box.

In one compound name, linking symbol, « _ » is automatically added up by software when validated (Cost per unit → Cost_per_unit).

A value is allotted to the variable name as soon as the latter is defined, and its name is added up to the scrolling list of variables being used. Activating the latter helps display the features of preliminarily-defined variables.

Button  allows to delete a preliminarily-defined variable, selected in scrolling list.


Button  allows to generate a document containing all characteristics of the variables and results previously entered.

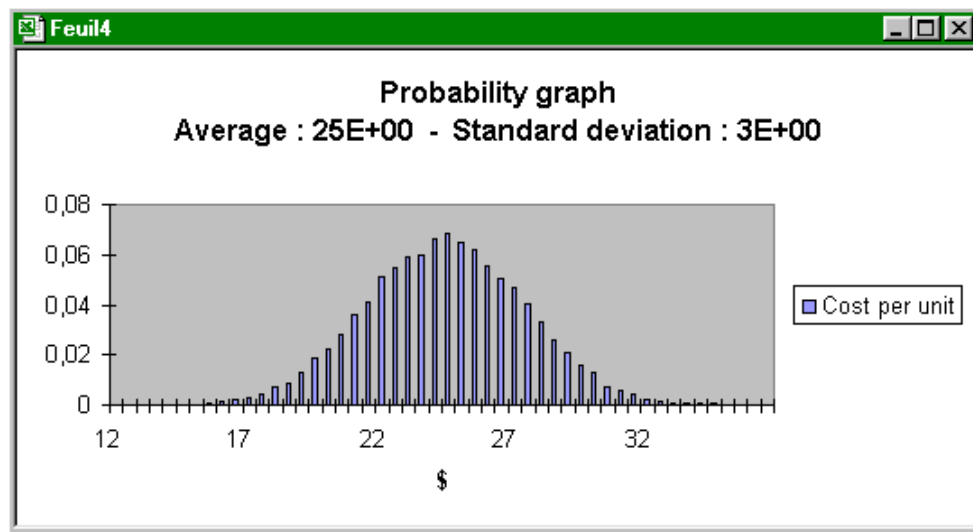



The screenshot shows a dialog box with a blue title bar labeled 'Feuil2'. It contains two tables. The first table, titled 'VARIABLES', has columns for NAME, LAW, PARAMETER 1, PARAMETER 2, PARAMETER 3, MIN, MAX, and UNIT. The second table, titled 'RESULTS', has columns for NAME, ADDRESS, and UNIT.

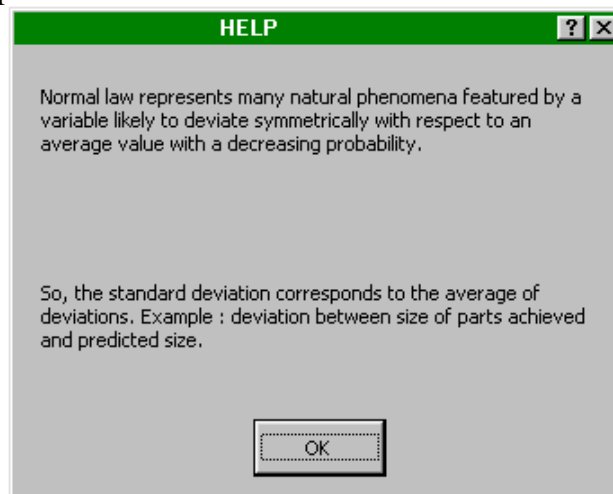
VARIABLES							
NAME	LAW	PARAMETER 1	PARAMETER 2	PARAMETER 3	MIN	MAX	UNIT
Cost_per_unit	NORMAL	25	2		0	100	\$
Launching_cost	TRIANGULAR	3800			2000	4500	\$
Number_of_sales	TRIANGULAR	1500			200	5000	
Price	TRIANGULAR	35			30	50	\$

RESULTS		
NAME	ADDRESS	UNIT
Result	R10C3	0

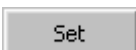
Button  allows to perform a simulation of selected law, then to display the results thereof as in example below.

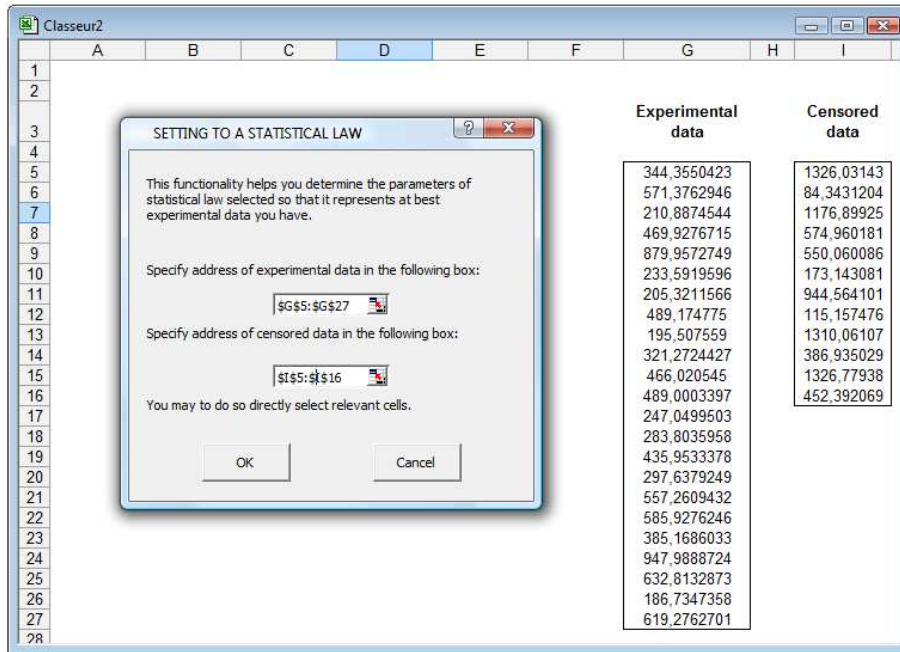


Button  allows to initiate an online hotline specifying the operating conditions of selected law as shown in example thereafter.

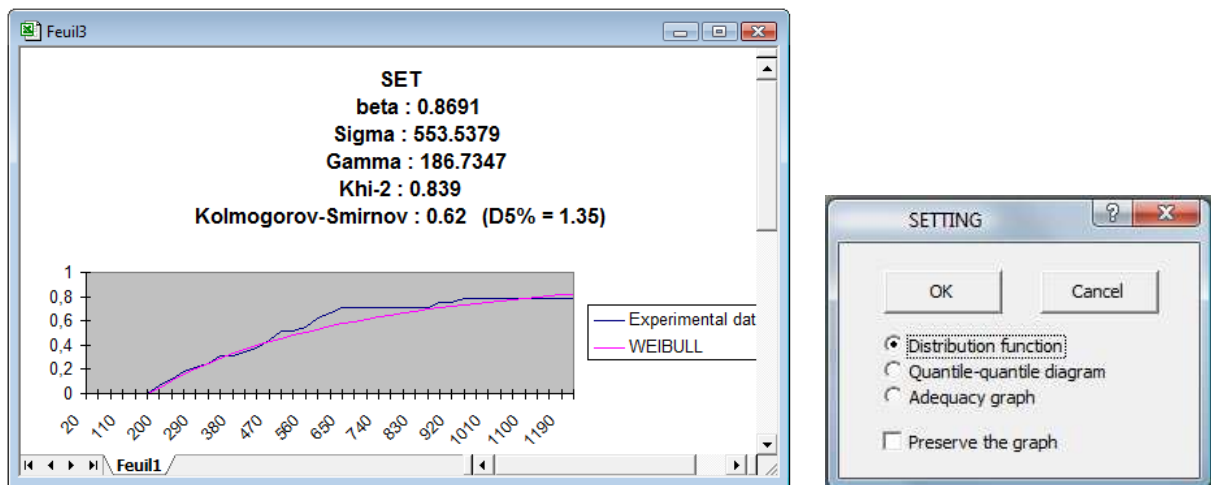


3.1.2 Setting

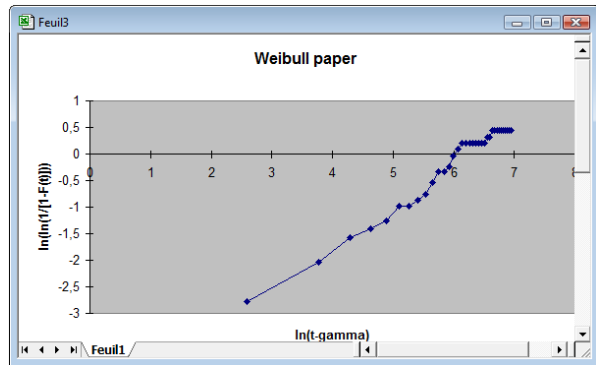
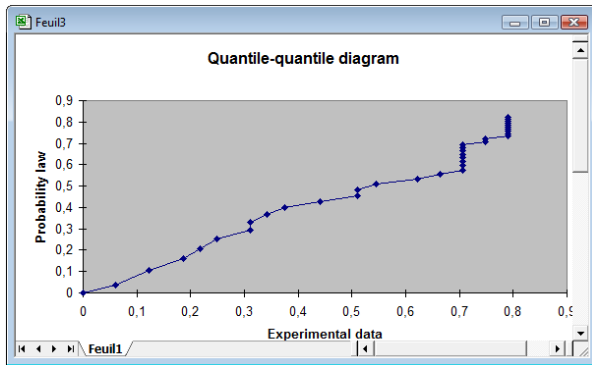
Button  allows to set the law selected from experimental data. When activated, it initiates the display of the following dialog box which helps user inform the chronological-series address through a selection by simply using computer mouse. Such series should be preliminarily entered in line or column on a calculation sheet (but not necessarily the one being selected).



From all values of series, setting is achieved by software using maximum-likelihood method (optimization achieved using Simplex method). At completion of such setting, software displays the experimental distribution function and function of law obtained together with statistical-test results (Khi-2, Kolmogorov-Smirnov) enabling user to validate law's selection.



The diagram quantile-quantile and other graphics (Weibull paper ...) are proposed for the user to visually judge the adequacy of the model.




If setting is accepted by user, dialog box « Define a variable » is newly displayed with optimal parameters of the informed law.

3.1.3 Personalized Function

Main features of software-proposed probability laws are set forth in Section 4 of manual hereof.

However, a specific law called « Personalized » helps user define any law by entering directly its distribution function on processing sheet or by having the latter generated by software from experimental data.

After pressing button , it specifies to do so the address of sheet where the distribution function of such law can be found, as in example hereunder (cost variable), and possibly the address of chronological series if function shall be initiated.

HELP : PERSONALIZED LAW

Such functionality allows you to define any type of statistical law from its distribution function defined on processing sheet.

Defined by a 2-column matrix (values and growing probabilities from 0 to 1), such function may be entered by yourself or generated directly by software from a chronological series.

State address of matrix's upper left cell in box below :

Specify, if applicable, address of chronological series in box below :

(select to do so relevant cells)

OK Cancel

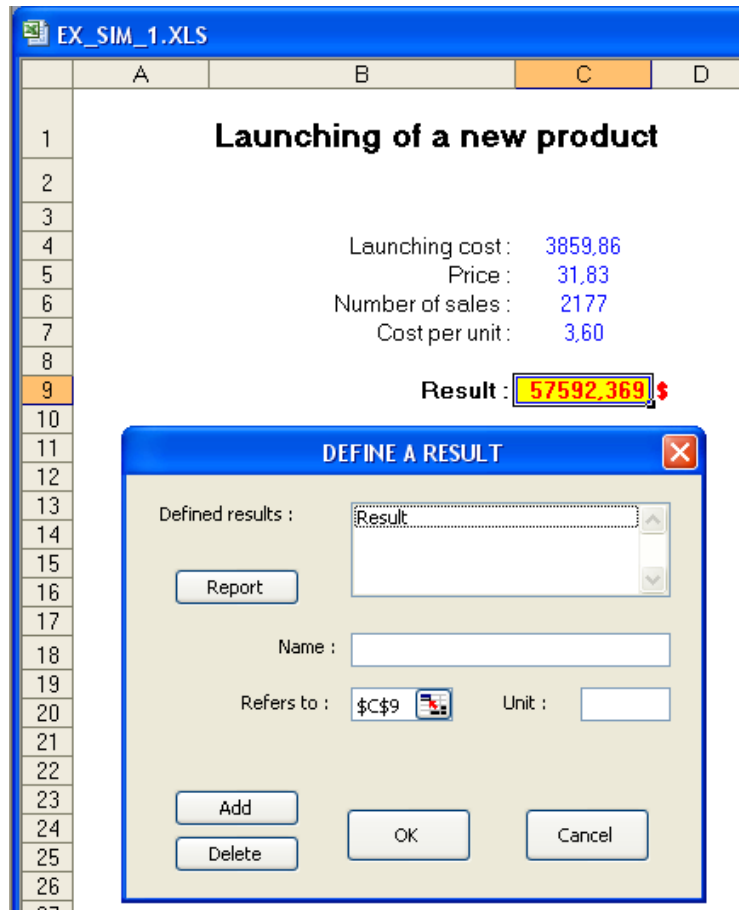
Cost (personalized law)	
0	0
0.5	0.07692308
1	0.15384615
2	0.23076923
5	0.30769231
7	0.38461538
8	0.53846154
9	0.61538462
11	0.76923077
12.5	0.84615385
13	0.92307692
15	1

3.2 Define a result


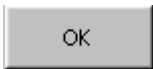
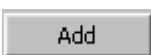

This operation consists in allotting names to calculation sheet cells and consider them as processing results.

Command "**Define a result**" of menu "**Simulation**" allows to define a result using a dialog box identical to that used to define input variables.

Its application is illustrated in example below :



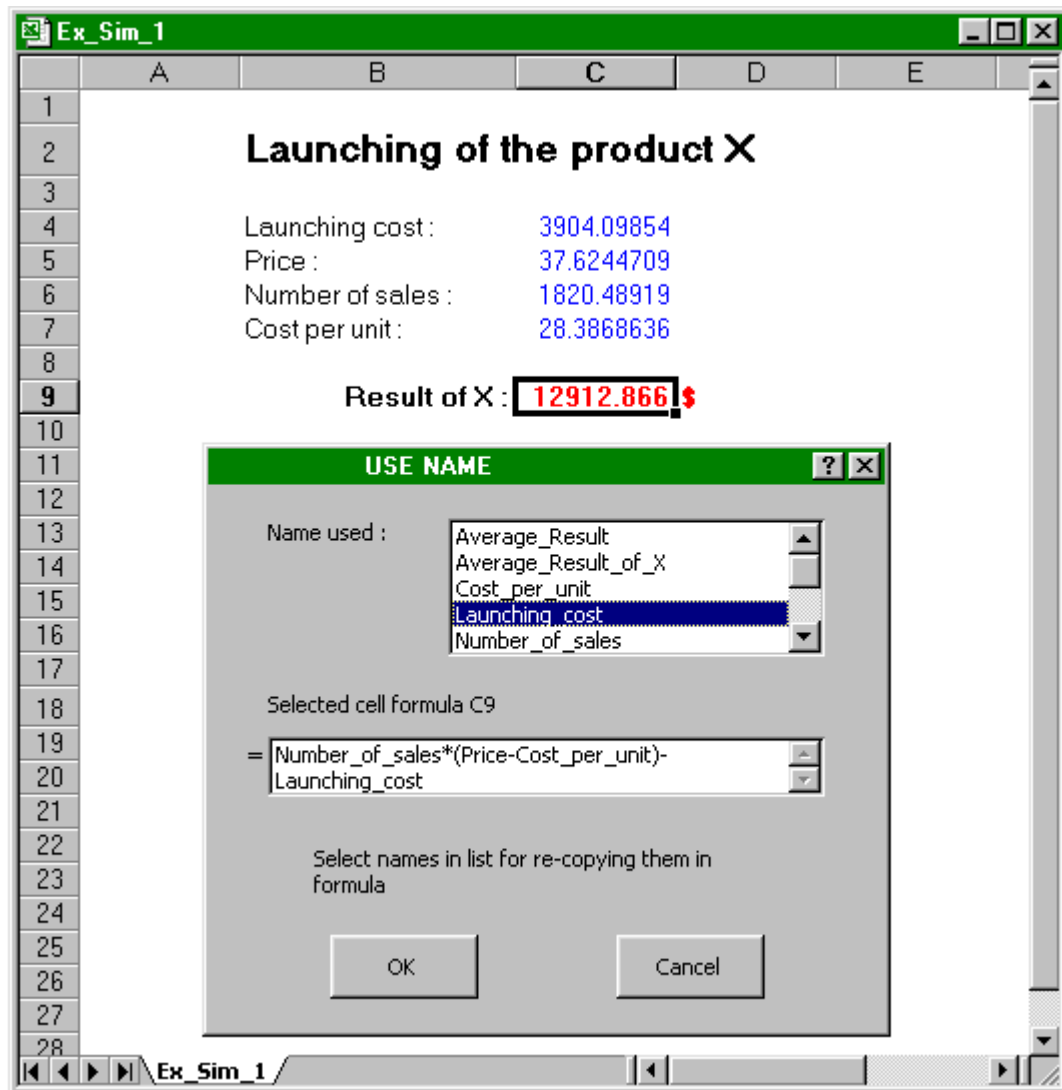
Active cell address is proposed by default in dialog box as well as any possible name written out on sheet close to the latter.

Buttons , ,  and  are used just the same way as those of dialog box "**Define a variable**".

3.3 Using Names

Command "Use names" of menu "Simulation" enables to enter formulas in sheet cells, by using preliminarily-defined variable or result names, with no need to re-enter them.

So in example below, formula of result of product X may be easily entered in active cell, using software-proposed dialog box, by selecting names in scrolling list.

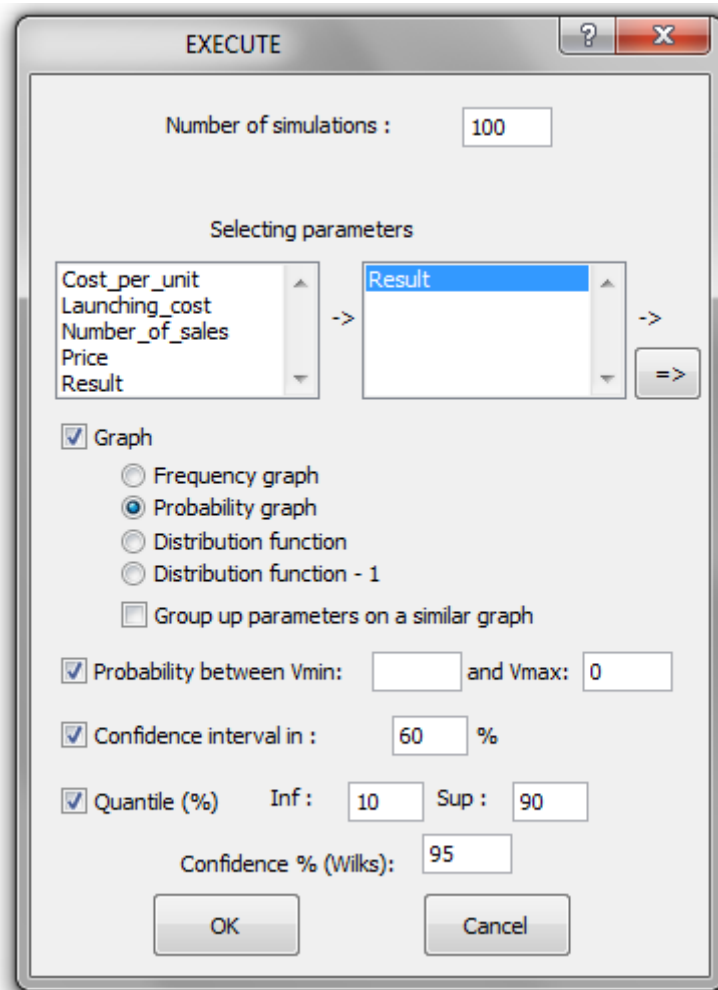


Formula = Number of units sold * (selling price - Cost per unit) – Launching Cost

Remark : entering operators and parentheses requires to be preliminarily placed in dialog box's box by using mouse.

3.4 Executing Simulation

Command "Execute" of menu "Simulation" allows to display dialog box below :



Input or result variables to be subject to a simulation are to be selected in left list including all preliminarily-defined variable and result names. A mouse click on one of names initiates such name in the right-hand list of variables selected. A mouse click on one of right list's names makes it disappear from the list hereof. Clicking on the double arrow makes them all disappear.

The number of simulations required is limited to 16 000. The more such number is high, the better the accuracy of results obtained, but this is detrimental to the processing time. Therefore, it is recommended to start simulation with a low number (100) then carry on subsequently by increasing such number.

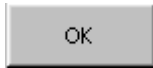
Results of simulation may be presented in frequency graph, probability graph, distribution function or 1 – distribution function.

Variables may be grouped up on a same graph or be subject to separated graphs.

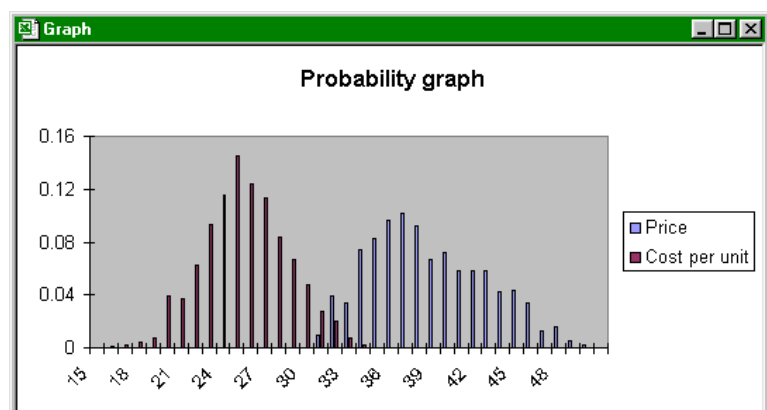
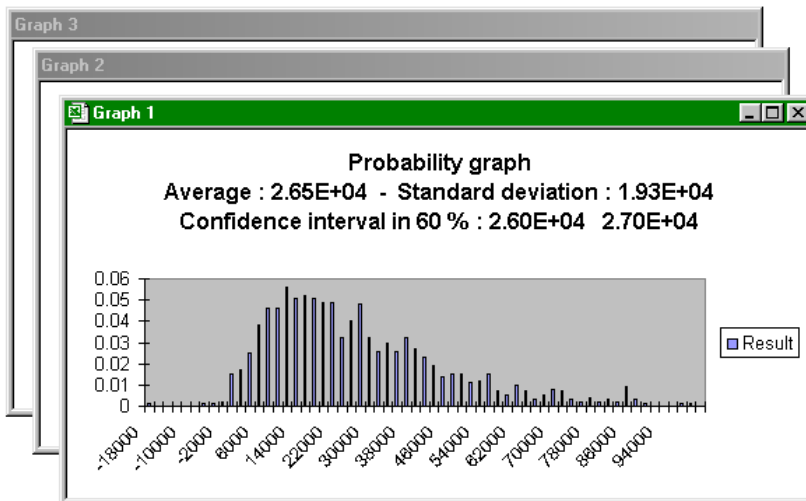
The probability to be in an interval can be estimated as that of obtaining a negative result ($V_{max} = 0$).

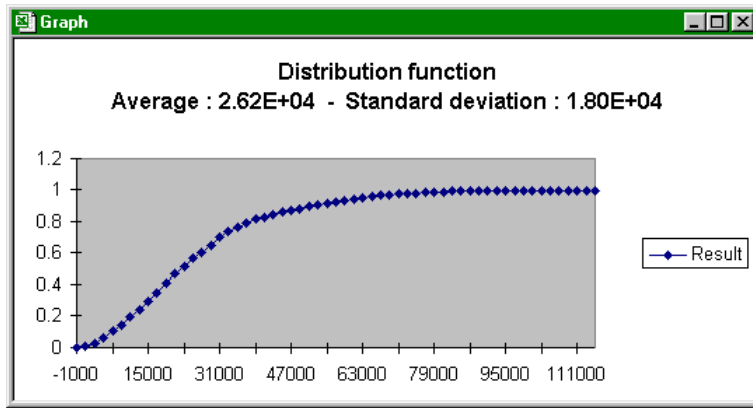
A confidence interval around the average value of each result can be evaluated according to a confidence level.

Two values of quantile (upper = Sup. and lower = Inf.) can be estimated either directly those of the simulated sample, those of the population with a confidence level by applying the method of Wilks (the lower bound for the lower quantile or upper bound for the upper quantile).

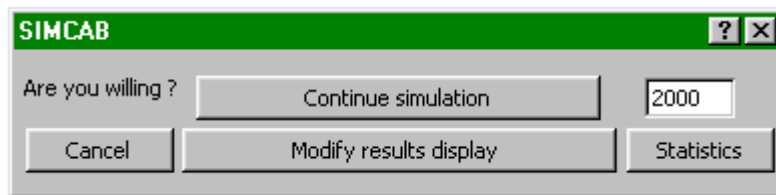



Initiating button runs therefore simulation and controls the requested-results display as shown in examples below.

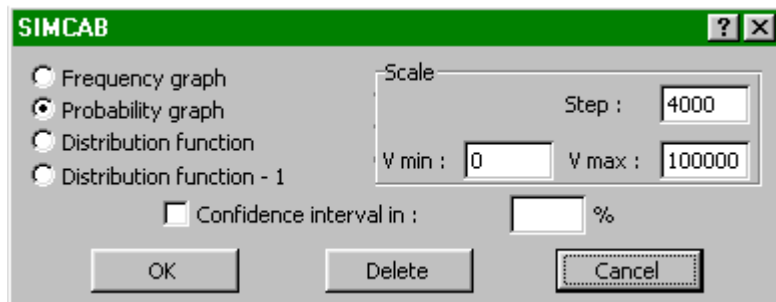




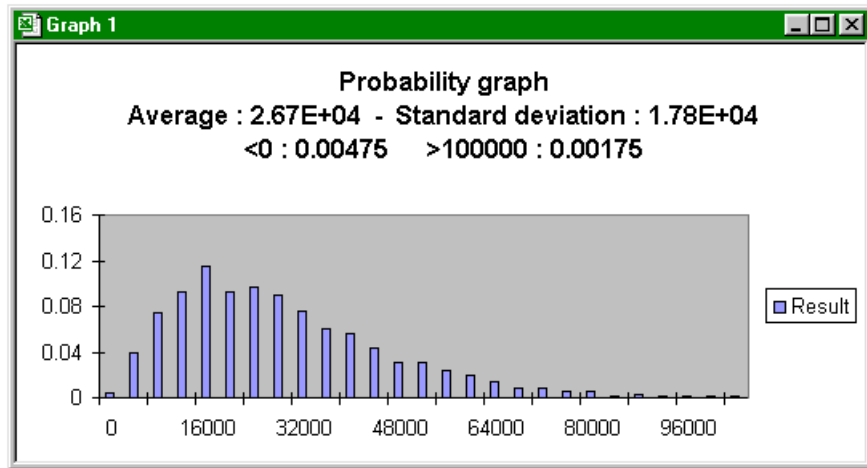
These different charts are accompanied by following dialog box which allows to carry on simulation (doubling of number of achieved simulations is proposed by default), to modify results overview, or to perform on results various statistical processing shown in chapter 3.5.



Pressing button  initiates the display of following dialog box allowing to modify the type of graph selected, modify minimum and maximum limiters as well as the viewing step, and possibly request the confidence-interval display..



Modifying one of limiters initiates the display on graph of probability that variable be beyond that limiter as shown in such example where probability that result be a loss is thereby immediately provided.



Remarks :

All graphs obtained are in specific calculation sheets which include all results of relevant simulation.

Performing the simulation initiates the creation of two additional names for each variable defined as result, « Average_Result » and « Standard_Deviation_Result », which correspond to the average value and standard deviation of variable with name « Result », respectively. Such names are specially used for optimization purposes (See chapter 3.4).

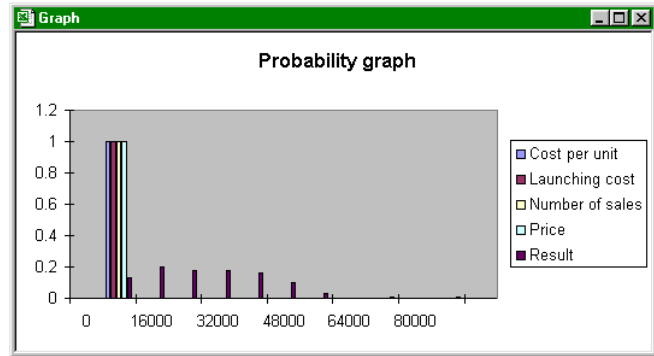
In the same way, the names "CMax_Result", "CMin_Result", "Confidence_rate" and "Nb_simu" are also created if the calculation of the confidence interval is required. These names correspond respectively at the lower and higher boundaries of the confidence interval, the corresponding rate and the number of simulations carried out.

Finally, the names "quantile_inf_Résultat", "quantile_sup_Résultat", "Quantile_inf" and "Quantile_sup" and "Confiance_quantile" are also created if the calculation of quantiles is requested. These names correspond to the values of the quantiles of the distribution of results for the corresponding lower and upper quantiles possibly considering a confidence level by applying the method of Wilks.

3.5 Statistics

3.5.1 Statistical Processing

After selecting a simulation results sheet (graph), Command "**Statistics**" of menu "**Simulation**" enables to perform on results various statistical processing operations by ticking among various options proposed in a dialog box. Example below shows results obtained for all such options.



STATISTICS ? x

?	<input checked="" type="checkbox"/> Average		
?	<input checked="" type="checkbox"/> Standard Dev	<input checked="" type="radio"/> Sample	<input type="radio"/> Population
?	<input checked="" type="checkbox"/> Variance	<input type="radio"/> Sample	<input checked="" type="radio"/> Population
?	<input checked="" type="checkbox"/> Median		
?	<input checked="" type="checkbox"/> Kurtosis		
?	<input checked="" type="checkbox"/> Asymmetry Coefficient		
?	<input checked="" type="checkbox"/> Confidence interval	90 %	
?	<input checked="" type="checkbox"/> Covariance matrix		
?	<input checked="" type="checkbox"/> Matrix of linear-correlation coefficients		
?	<input checked="" type="checkbox"/> Diagram of correlation between variables :		

Price

Launching cost

Number of sales

Price

Result

Number of sales

Price

Result

	Cost per unit	Launching cost	Number of sales	Price	Result
Average	24.9482655	3359.71212	2168.09583	38.2366598	24897.9743
Standard deviation (S)	2.04124964	523.573472	939.323297	4.39920054	14825.1086
Variance (P)	4.1250331	271387.889	873504.973	19.1594358	217586007
Median	24.9596536	3381.79924	2082.26494	37.5254686	23346.835
Kurtosis	-0.4250238	-0.448271	0.02863324	-0.70982931	1.58424155
Asymmetry	-0.12483869	-0.34137345	0.54261496	0.53613326	0.8535114

Confidence interval in 90 %

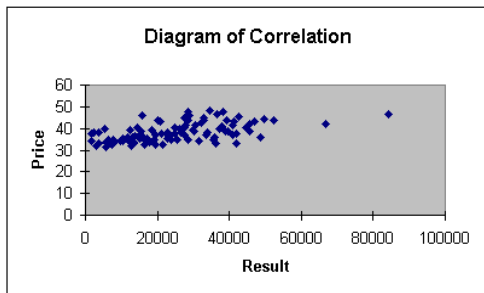
	Cost per unit	Launching cost	Number of sales	Price	Result
Borne min.	24.61251	3273.59198	2013.59095	37.513056	22459.4619
Borne max.	25.2840211	3445.83226	2322.6007	38.9602636	27336.4867

Covariance Matrix


	Cost per unit	Launching cost	Number of sales	Price	Result
Cost per unit	4.1250331	33.9484209	306.566201	-0.04627325	-4113.04749
Launching cost	33.9484209	271387.889	-8282.82408	-61.0740738	-313286.478
Number of sales	306.566201	-8282.82408	873504.973	-246.259575	9744075.99
Price	-0.04627325	-61.0740738	-246.259575	19.1594358	35532.9434
Result	-4113.04749	-313286.478	9744075.99	35532.9434	217586007

Matrix of Linear-Correlation Coefficients

	Cost per unit	Launching cost	Number of sales	Price	Result
Cost per unit	1	0.03208563	0.16150198	-0.00520505	-0.13728862
Launching cost	0.03208563	1	-0.01701181	-0.02678368	-0.04076908
Number of sales	0.16150198	-0.01701181	1	-0.0601962	0.70679341
Price	-0.00520505	-0.02678368	-0.0601962	1	0.55033147
Result	-0.13728862	-0.04076908	0.70679341	0.55033147	1



3.5.2 Meaning of Processing Operations

An online help accessible through buttons  allows to remind user of the meaning of his various options :

Average :

Enters the average value of simulation results (arithmetical average).

Standard Deviation :

Standard deviation is a scattering measurement of values from a population with respect to their average value (square root of variance).

Enters standard deviation of simulation results in population position,
or

Enters standard deviation of a population assessed from simulation results considered as a sample of this population in sample position.

Variance :

Variance is the arithmetical average of squares of deviations between values of a population and their average value.

Enters variance of simulation results in population position,
or

Enters variance of a population assessed from simulation results considered as a sample of this population in sample position.

Median :

Enters median of simulation results (value splitting in two halves the series of results ordered).

Kurtosis :

Enters Kurtosis (or coefficient of flattening) of simulation results.

A positive Kurtosis corresponds to a relatively thorough distribution compared to a normal distribution.

A negative Kurtosis corresponds to a relatively flattened distribution compared to a normal distribution.

Asymmetry Coefficient :

Enters the asymmetry coefficient of simulation results which features the non-symmetry of distribution with respect to median.

A positive coefficient corresponds to a distribution shifted towards positive-value section.

A negative coefficient corresponds to a distribution shifted towards negative-value section.

Confidence Interval :

Interval which includes the considered parameter with a probability equal to confidence level. Confidence interval depends on sample size (number of simulations) and on standard deviation of this sample.

Covariance Matrix :

Covariance features the linking intensity between two parameters (arithmetic average of products of deviations for each of them).

Enters the covariance matrix between the various simulated parameters.

Matrix of Linear-Correlation Coefficients :

This coefficient features the linking linearity between two parameters.

Enters matrix of linear-correlation coefficients between the various simulated parameters.

This coefficient may vary between 1 and -1.

Diagram of Correlation Between Variables :

Enters diagram of correlation between two selected parameters (cluster of points typical of couples x_i and y_i being simulated).

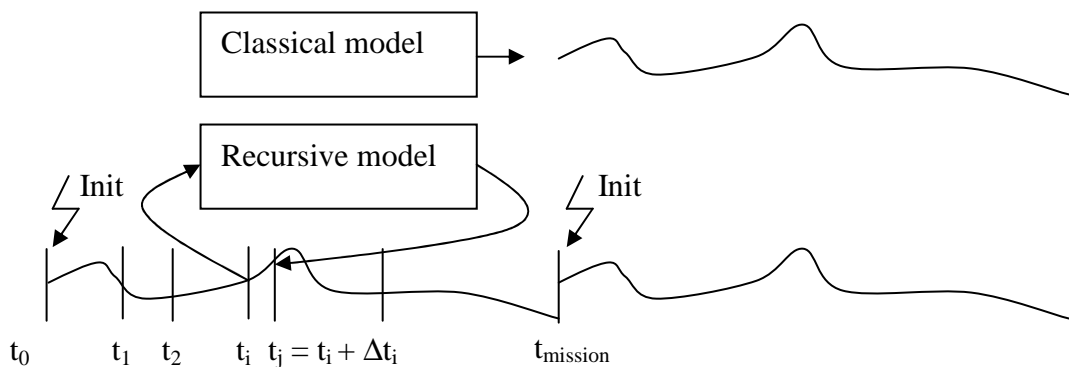
Both parameters should be preliminarily selected in both scrolling lists.

3.6 Treatment of the dynamic systems

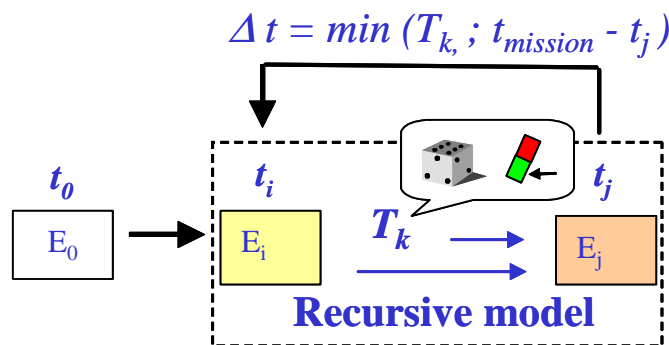
3.6.1 Recursive Modelling

a) Principle:

Recursive modelling does not describe the behaviour of a system during all its mission but only between two current moments t_i and t_j which corresponds to random state changes of the system (failure or repair for example) or to the crossing of characteristic thresholds by continuous variables in the case of hybrid systems (a mechanism of control activated when a parameter enters in zone of alarm for example). It results a simplified simulation, exclusively based on logical or calculation operators.



Each simulation carried out by the tool consists in recopying a certain number of times, during all the mission, the E_j state, defined in cells of the spreadsheet, in E_i state, defined in the same manner in other cells, from an initial state E_0 defined in addition, like illustrates it the following figure.

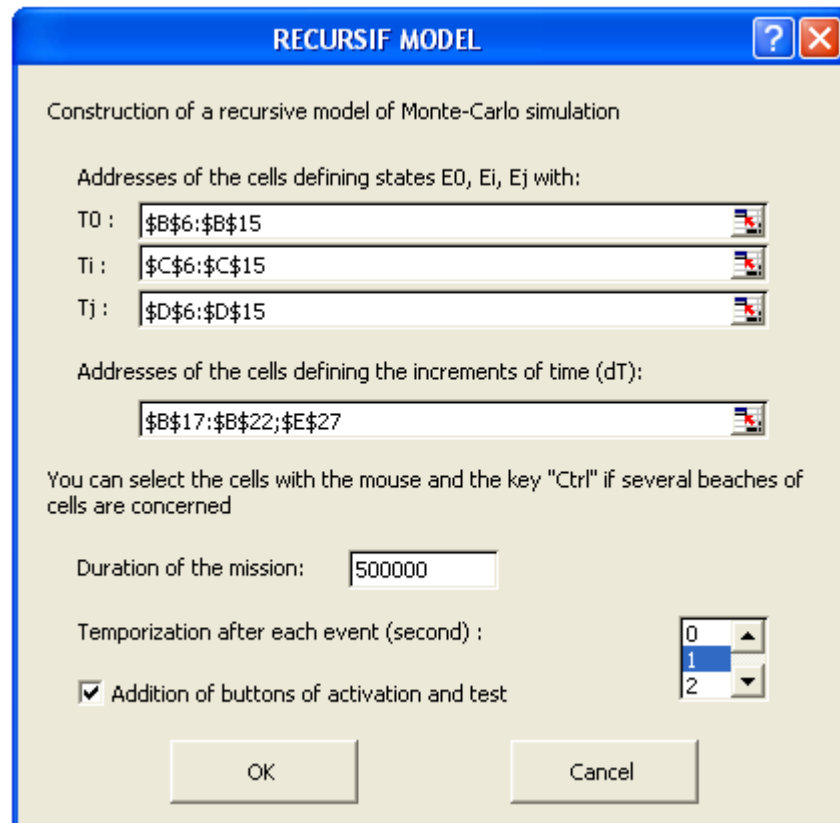


The increment Δt , considered by the tool, is the smallest computed value among various increments of times T_k defined in another cells of the spreadsheet. These times T_k are recalculated at each transition in the Markov case or calculated once and then decremented until they are taken into account otherwise.

Simulation can be carried out in step by step to validate the models, or during a complete mission which is simulated a great number of times in order to reach the required precision.

b) Implementation:

Command "**Recursif Model**" of "**Simulation**" menu allows getting the following dialog box used to define the addresses of the various cells defining the states E_0 , E_i and E_j and the increments of time as well as the duration of the mission.



Each address of cells can be broken up into multiple secondary addresses by the use of the mouse and the key "Ctrl".

Button of activation and test (initialization, step by step, simulation) can be copied on the sheet in order to facilitate the validation of the model and a temporization after each event can be required (in second).

"INIT" parameter is also created in the worksheet to facilitate the development of the model of simulation. This one is with the True state with initialization then with the False state during simulation.

To allow the user to build its simulation recursive model, the tool offers random parametric functions to simulate various laws of probability on the spreadsheet (macro-functions).

These functions start with "L_", followed by 3 first letters of the probability law and corresponding 5 arguments in brackets separated by a comma, as in the following example:

$$=L_Wei(2,500,100) \rightarrow 972.035706$$

The significance of the arguments of these functions is given in the following table:

Law	Code	Argument 1	Argument 2	Argument 3	Argument 4	Argument 5
BETA	BET	N	P		Min	Max
BINOMIAL	BIN	Probability	Nb of tests		Min	Max
ERLANG	ERL	Lambda	K		Min	Max
EXPONENTIAL	EXP	Lambda			Min	Max
GAMMA	GAM	Lambda	Beta		Min	Max
GEOMETRICAL	GEO	Probability			Min	Max
GUMBEL	GUM	a (position)	b (scale)		Min	Max
HYPERGEOMETRIC	HYP	Nb good	Nb of tests	Nb wrong	Min	Max
LOGNORMAL	LOG	Average	S. deviation		Min	Max
NORMAL	NOR	Average	S. deviation		Min	Max
PARETO	PAR	K	Min value		Min	Max
PEARSON	PEA	Nu			Min	Max
POISSON	POI	m			Min	Max
TRIANGULAR	TRI	Probable			Min	Max
UNIFORM	UNI				Min	Max
WEIBULL	WEI	Beta	Sigma	Gamma	Min	Max

By way of illustration, the examples of recursive models presented hereafter are proposed in the on line help:

a) Monitoring mechanism of liquid level in a tank (hybrid system)

This mechanism of control allows the regulation of liquid level in a tank at a minimum or maximum threshold according to relative flows' between the filling pumps and the emptying valve.

These components are repairable and have each one 2 possible modes of failure (blocked ON or OFF for the pumps and blocked in the current state Open or closed for the valve).

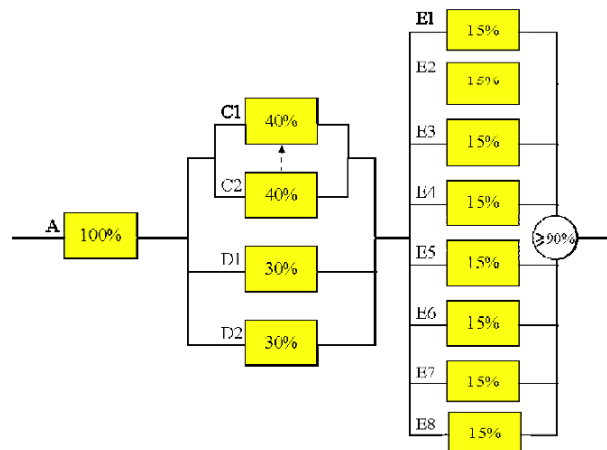
	T ₀	T _i	T _j	
	0	35721,0886	38528,507	T: temps courant (hr)
h	3	2,00	2,00	h: height of water (m)
Pump 1	1	1	2	1: Ok - 2: bloqued ON - 3: bloqued OFF
Pump 2	1	1	1	1: Ok - 2: bloqued ON - 3: bloqued OFF
Valve	1	1	1	1: Ok - 2: bloqued Open - 3: bloqued Closed
Nb overflow	0	0	0	Cumulated number of overflows
T overflow	0	0,00	0,00	Cumulated duration of overflows (hr)
V overflow	0	0,00	0,00	Lost cumulated volume (m3)
Nb emptying	0	0	0	Cumulated numbers of emptyings
T emptying	0	0,00	0,00	Cumulated duration in emptying (hr)
V emptying	0	0,00	0,00	Cumulated volume not provided

Pump_1_OK	2807,42	MTBF P1	50000	λ P1	0,00002
Pump_1_NOK		MTTR P1	5000	μ P1	0,0002
Pump_2_OK	23986,32	MTBF P2	50000	λ P2	0,00002
Pump_2_NOK		MTTR P2	5000	μ P2	0,0002
Valve_OK	48185,32	MTBF V	80000	λ V	1,25E-05
Valve_NOK		MTTR V	10000	μ V	0,0001

Tank surface (m ²)	50	Sr	Δ flow	0	(l/h)
Tank height (m)	6	Hr	dh/dt	0	(m/h)
Min threshold (m)	2	S _{min}	h _{threshold}	-2,00	(m)
Max threshold (m)	4	S _{max}	T _{threshold}	#####	(h)
Pump flow 1 (l/h)	100	D_1			
Pump flow 2 (l/h)	100	D_2			
Valve flow (l/h)	150	D_V			

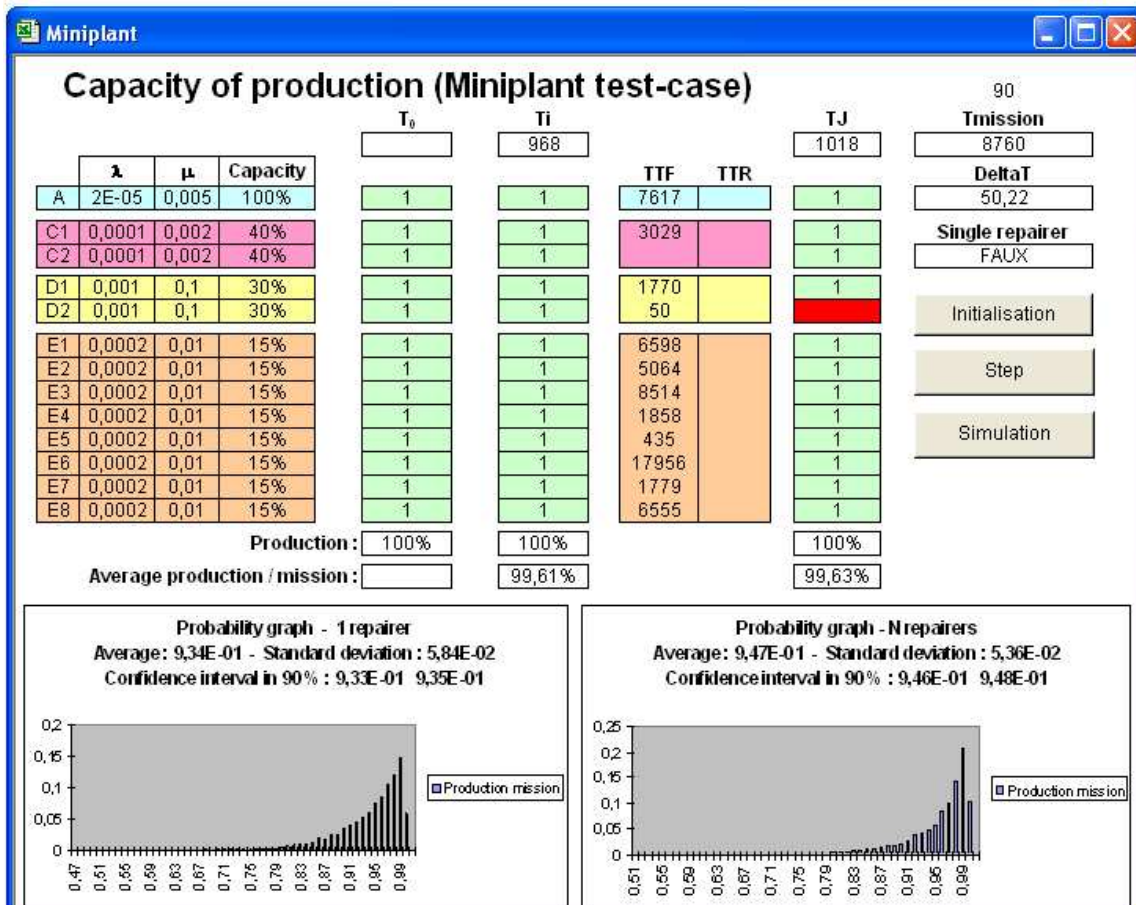
	Pump 1	Pump 2	Valve
h > Max threshold	stopped	stopped	Open
Max threshold ≥ h ≥ Min threshold	active	stopped	Open
h < Min threshold	active	active	Closed

b) Capacity of production (Miniplant test-case)



MINIPLANT relates to a factory of production whose capacity is equal to lowest capacities of three subsystems in series.

- Each block contributes to the output of the unit of which it forms part. The blocks C1 and C2 are in cold passive redundancy (C2 functions only in the event of C1 failure with a null failure rate to the state OFF) and the E1: E8 blocks function only so at least 6 of them are operational in order to exceed a minimal threshold of 90% of capacity for this last subsystem.
- Two policies of maintenance are considered: a repairer per block or only one repairing per subsystem with repair of the blocks in the order of appearance of the failures.



MINIPLANT + differs from the MINIPLANT test-case by the following elements:

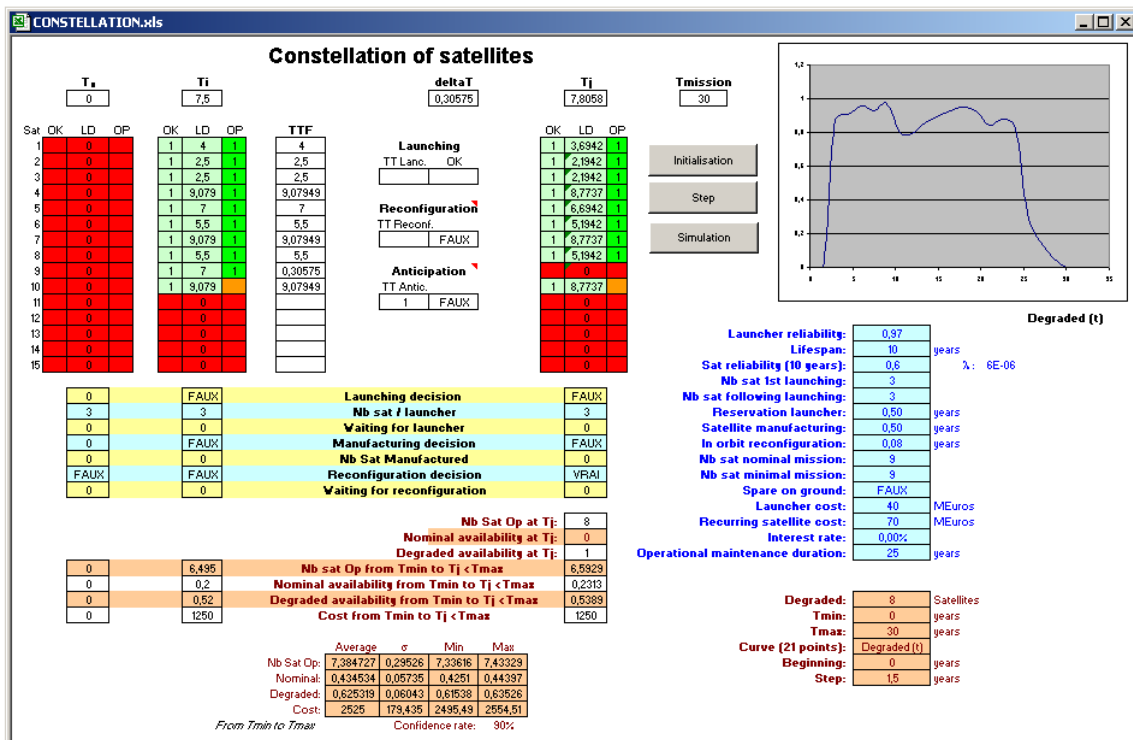
- Introduction of a stochastic dependence: The C2 element of the cold redundancy is affected of a failure rate $\lambda_{OFF} = \lambda_{ON} / 10$ and of a failure rate to the request $\gamma = 1\%$.
- Introduction of a phenomenon of wear and a periodic maintenance: it is added to element A an element A', in series, subjected to wear according to a Weibul law ($\beta = 5, \gamma = 0, \sigma = 4000$) and replaced periodically (3000 hours after T0 and preventive or corrective maintenance actions).
- Possibility of choosing the number of repairers per subsystem (of 1 to N with evaluation of the particular case: 1 repairer for subsystem 2 and 3 repairers for the subsystem 3).
- Taken into account of a production request modified every 2000 hours on average and distributed uniformly between 60 % and 130 % (evaluation of the proportion of the really satisfied request).

Compared to MINIPLANT +, MINIPLANT Pro considers cost data in order to optimize the means of production:

- The maintenance cost of the A' element is one cost-unit (annual Cost = 8760/Period of maintenance).
- The annual depreciation of each set A, C1:C2, B1:B2, E1:E8 is 10 cost-units for their initial capacity, that is to say respectively 100%, 40%, 30% and 15%, and is proportional to this capacity which can be modified in a ratio from 0,5 to 2.
- The annual cost of each repairer of the sets C1:C2 + B1:B2 and E1:E8 is 1 cost-unit.

c) Model of satellites constellation deployment and maintenance

The constellation consists of N operational satellites plus spares (15 to the maximum simultaneously in orbit). Those can break down and have each one a limited lifespan due to their propellant capacity.



3.6.2 Simulator of system architecture

This tool can automatically generate a model of recursive simulation from a table filled in by the user.

Architecture

Equipment		Failure		Repair		Passive					Stock of spare				
N°	Name	Law	λ	Law	μ	Condition _{OFF}	Law	λ_{OFF}	Law	T _{Reconf}	γ	N°	S	Law	TAT
1		EXP		EXP			EXP		EXP					EXP	
2		EXP		EXP			EXP		EXP					EXP	
3		EXP		EXP			EXP		EXP					EXP	
4		EXP		EXP			EXP		EXP					EXP	
5		EXP		EXP			EXP		EXP					EXP	
+															

Operation	
N°	Condition
1	
2	
3	
4	
+	

The table includes the characteristics of failure, repair, reconfiguration and logistic of the system components, and a logical description of nominal or degraded mode of operation.

The operating conditions and the conditions maintained in the passive state are defined using the operators AND (*), OR (+), NOT (~) and combination m among n : m/n(i + ... + k).

Architecture

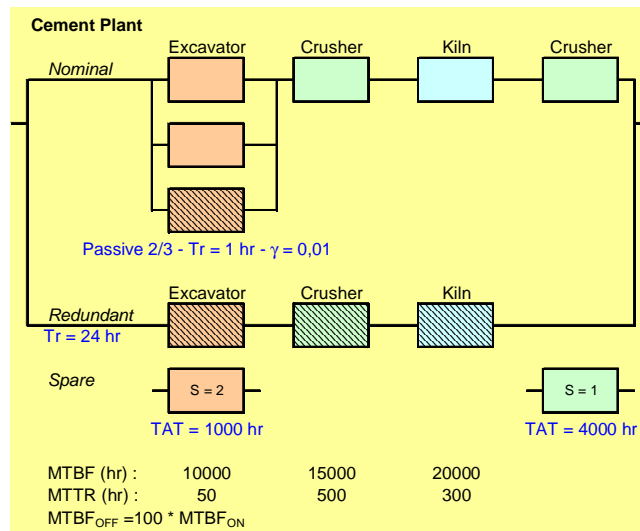
Equipment		Failure			Repair		Markov
N°	Name	Law	Parameters		Law	μ	
1		EXP			EXP		TRUE
2		WEI			EXP		FALSE
3		EXP			EXP		TRUE
4		EXP			EXP		TRUE
5		EXP			EXP		TRUE
+							

Given by default, the exponential probability law can be replaced by another law. Then, additional columns allow to enter the law parameters and to indicate if the Markov assumption must be maintained for the equipment.

The buttons "Passive" and "Spare" can hide or show the relevant columns in the table. The button "Simulator" allows to generate the simulation model and the button "RBD" draws the Reliability Block Diagram as a fixed picture or animated by the step by step simulation.

Many messages accessible by the mouse (red dots in the upper left cell) provide information about input formats.

As an illustration, the example of a cement plant, below, is presented in the online help:



Equipment	Failure	Repair	Passive						Stock of spare						
			Failure OFF		T _{Reconf}		γ	N°	S	TAT					
N°	Name	Law	λ	Law	μ	Condition OFF				Law	λ _{OFF}	Law	T _{reconf}		Law
1	Excavator 1	EXP	0,0001	EXP	0,02		EXP		EXP				2	EXP	1000
2	Excavator 2	EXP	0,0001	EXP	0,02		EXP		EXP			1		EXP	
3	Excavator 3	EXP	0,0001	EXP	0,02	1*2	EXP	1E-06	EXP	1	0,01	1		EXP	
4	Crusher 1	EXP	7E-05	EXP	0,002		EXP		EXP				1	EXP	4000
5	Kiln 1	EXP	5E-05	EXP	0,0033		EXP		EXP					EXP	
6	Crusher 2	EXP	7E-05	EXP	0,002		EXP		EXP			4		EXP	
7	Excavator 4	EXP	0,0001	EXP	0,02	/3(1+2+3)*4*5*	EXP	1E-06	EXP	24		1		EXP	
8	Crusher 3	EXP	7E-05	EXP	0,002	/3(1+2+3)*4*5*	EXP	7E-07	EXP	24		4		EXP	
9	Kiln 2	EXP	5E-05	EXP	0,0033	/3(1+2+3)*4*5*	EXP	5E-07	EXP	24				EXP	

Operation		
N°	Name	Condition
1	Nominal	2/3(E1+E2+E3)*E4*E5*E6
2	Degraded mode 1	1/3(E1+E2+E3)*E4*E5*E6
3	Redundant	E7*E8*E9
4	Degraded mode 2	F2+F3

The conditions maintained in the passive state are defined from the operative state (no failure) of equipments identified by their number. Thus, the excavator 3 is not used when the first 2 work. It is operational after an hour with a solicitation failure probability of 1%. It uses the same stock of spare equipments that 1, which consists of 2 units with a restock time of 1000 hours. The equipment order in the table defines the allocation order of spares in case of a stock split and it is decremented at the end of each repair.

The operating conditions are defined from the activation state (ON state) of equipment identified by numbers preceded by the letter E, or other operating conditions preceded by the letter F.

	T0	Ti				Tj	DeltaT
	0	0				0	0
Equipments			TTF	TTR	TTS		
E1 :	1	1	12178,69			1	
E2 :	1	1	1601,75			1	
E3 :	1	1	4270,96		0,00		
E4 :	1	1	12290,43			1	
E5 :	1	1	15961,14			1	
E6 :	1	1	6358,16			1	
E7 :	1	1	23221,46		0,00		
E8 :	1	1	18721,85		0,00		
E9 :	1	1	26882,74		0,00		
Stocks			TAT				
S1 :	2	2				2	
S4 :	1	1				1	
Operations							
F1 :	1					1	
F2 :	1					1	
F3 :	1					0	
F4 :	1					1	
Average/mission				<i>Markovian Simulator</i>			
F1 :						1	
F2 :						1	
F3 :						0	
F4 :						1	

The state of equipments, stocks of spare and functions appear in 3 columns corresponding to time T0, Ti and Tj. The active state is characterized by the value 1 (green), the state of failure by the value 0 (red), and the passive state by the lack of character (grey).

The central cells (blue) correspond to the time before failure (TTF), before repair (TTR), before transition to active or passive state (TTS) or before restocking the spare (TAT). Additional cells are also used to calculate the average availability of different functions during the mission.

For non-Markovian, additional lines are added to each equipment as either repairable or passive with reconfiguration duration, and to each item of spare stocks that supply is independent.

	T0	Ti				Tj
	0	0				0
Equipments			TTF	TTR	TTS	
E1 :	1	1	747,58			1
						747,6
E2 :	1	1	2419,04			1
E3 :	1	1	87,44		0,00	
E4 :	1	1	5108,83			1
E5 :	1	1	18590,77			1
E6 :	1	1	1379,17			1
E7 :	1	1	7053,70		0,00	
E8 :	1	1	43432,13		0,00	
E9 :	1	1	61981,72		0,00	
Stocks			TAT			
S1 :	2	2				2
S4 :	1	1				1

Non-Markovian

3.6.3 Simulation of Markovian systems

Same manner that tool *SUPERCAB*, *SIMCAB* makes it possible to simulate the matrices of Markov, while offering the additional possibility to consider various probability laws of transition.

MAT :	1	2	3	4
1	-	8,0E-6	Nor(20 ;1)	
2		-	3,2E-4	
3		5,0E-4	-	
4	1,2E-2			-
INIT :				
	0,8	0,2	0	0
ETATS :				
	1	1	0	0

For this purpose the macro-function, `MARK_SIM`, are proposed by the tool to calculate the probability of being in the various states of the system, or in a combination of states, at the time T:

`"=MARK_SIM(MAT,INIT,STATE,T,N)"`

The argument `MAT` corresponds to matrix of transition rates in hour ⁻¹ (terms of main diagonal are automatically computed during the processing and empty cells are replaced by 0).

Associated exponential laws, the rates of transition can be replaced by other laws of probability, as in the example above (`Nor(20;1)` = Normal Law of average 20 and standard deviation 1), while preserving at the system its Markovian character (no memory after each transition).

Each of laws is defined by its first 3 letters followed by 5 arguments in brackets separated by a comma whose meaning is the same as those of random parametric functions to simulate various laws of probability on the spreadsheet.

Vector `INIT` corresponds to the probabilities of being in the various states at $T = 0$.

Vector `STATE` defines the combination of states to be evaluated (state 1 or 2 in the example). If this vector is not defined, the tool calculates the probability of being in state 1.

Argument `N` corresponds to the number of simulations to carry out before leading to the result.

`MARK_SIM` function may be used in matrix form. To do so, select a range of cells and press "block capital" and "CTRL" keys by entering the function.

Used in matrix form, `MARK_SIM` function helps displaying time T, probability Pr to be in the combination of states defined by vector `STATE`, or probabilities P1 to Pn if vector `STATE` is not defined. It gives such results for intermediate time values between 0 and T if range of selected cells includes various lines.

Following examples specify the formalism adopted for such function when used in matrix form.

a) Vector STATE is defined :

	2 columns or more		1 column
	Time	Pr	Pr
0	0	0,9	0,9
T/(Nblines -1)	100	0,82142808	0,82142808
	200	0,78539121	0,78539121
T	300	0,76749154	0,76749154

b) Vector STATE is not defined :

	1 column	2 columns	
	P1	P1	P2
0	0,8	0,8	0,1
T/(Nblines -1)	0,75790422	0,75790422	0,13709395
	0,74332265	0,74332265	0,15914719
T	0,73803747	0,73803747	0,17235284

	n columns			
	P1	P2		Pn
0	0,8	0,1	0,1	0
T/(Nblines -1)	0,75790422	0,13709395	0,06352386	0,04147797
	0,74332265	0,15914719	0,04206856	0,0554616
T	0,73803747	0,17235284	0,02945406	0,06015563

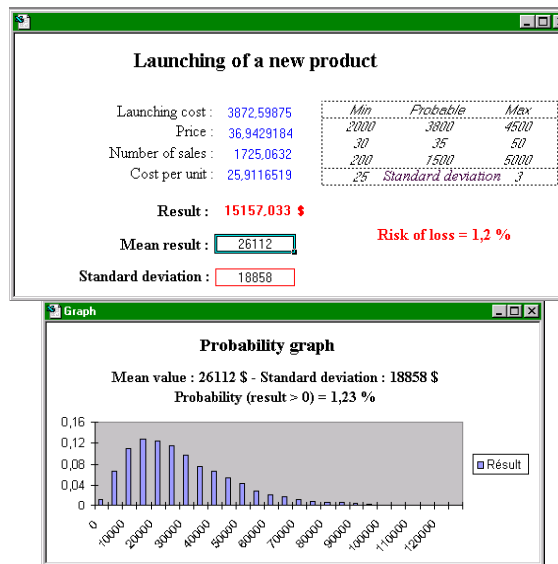
	n columns + 1 or more				
	Temps	P1	P2		Pn
0	0	0,8	0,1	0,1	0
T/(Nblines -1)	100	0,75790422	0,13709395	0,06352386	0,04147797
	200	0,74332265	0,15914719	0,04206856	0,0554616
T	300	0,73803747	0,17235284	0,02945406	0,06015563

4 Applications and Joint-Application Possibilities

Examples shown here are provided for demonstration in online help. Some of them illustrate the joint-application possibilities between *SIMCAB* and the other *CAB INNOVATION* softwares, either for controlling scattering in assessments performed by *SIMCAB+* operation safety software, or for achieving optimizations using *GENCAB* software from simulation results.

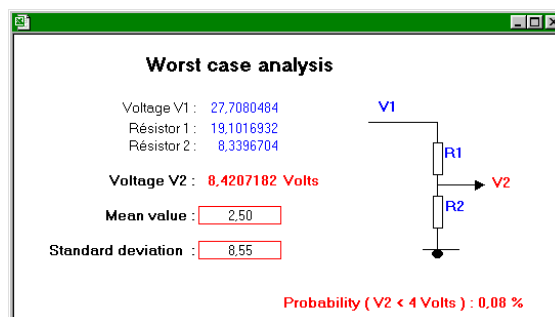
4.1 Controlling uncertainties

The following examples show in simple cases how dimensioning problems may be solved by the program in such highly different fields as marketing, electronics or mechanics.



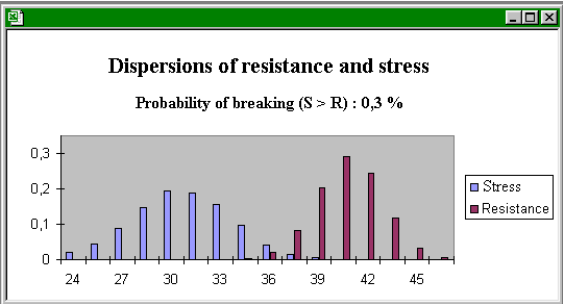
What result can we expect from a new product ?

This first example shows immediately the relevance, even for highly mere computations, to obtain results in distribution form, and not in selective assessment form



How to validate robustness of one design in the worst cases of operation ?

This second example illustrates a highly classical range of problems regarding design, that is how to make sure that design will be robust in the worst cases of nominal operations (assuming components going downhill, power supply variations, ageing, radiation doses received, ... etc.).

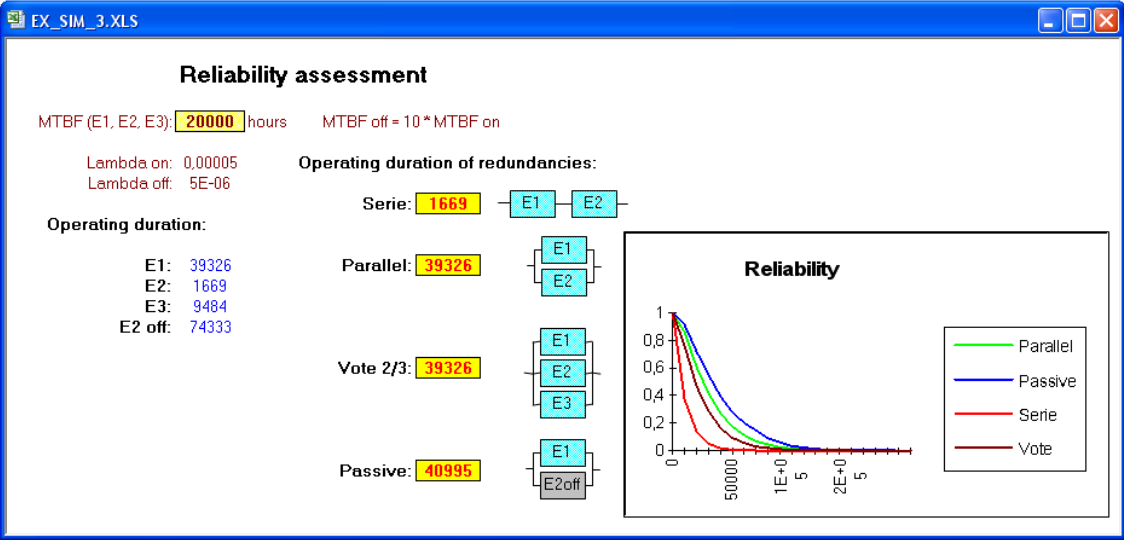


How to dimension properly a safety margin ?

This third example finally shows how, in mechanics, a dimensioning, assuming dispersions of materials resistance and stress undergone, provides a much better guarantee than if it is only based on using a simple safety coefficient (ratio between average resistance and average stress).

4.2 Simulation

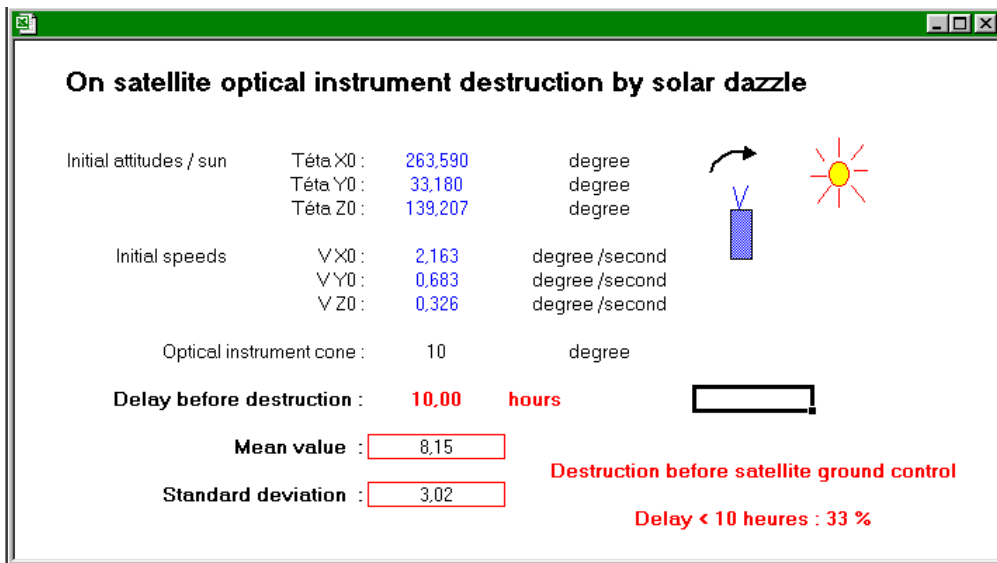
In addition to the assessment of scattering in calculations whose purpose is controlling uncertainties, simulation may also enable to face difficult results, even impossible to get through analytical computations. So, examples below show simulations achieved in the Operation Safety field.



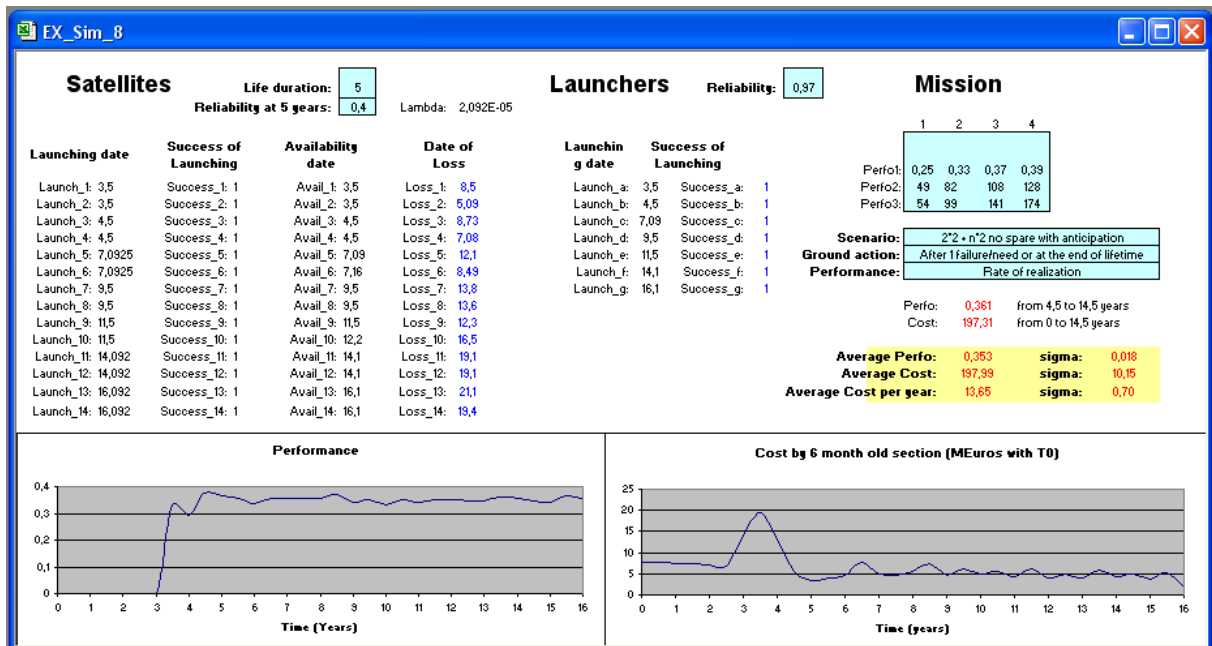
Reliability assessment

This example shows how redundancy equipment reliability may be assessed simply by simulation.

What is the impact of a servicing time following a breakdown ?



This example shows how the impact of a post-failure servicing time allowance upon equipment-destruction probability can be evaluated (risk of destructive solar dazzle of an optical instrument mounted on a satellite which is no longer momentarily controlled).



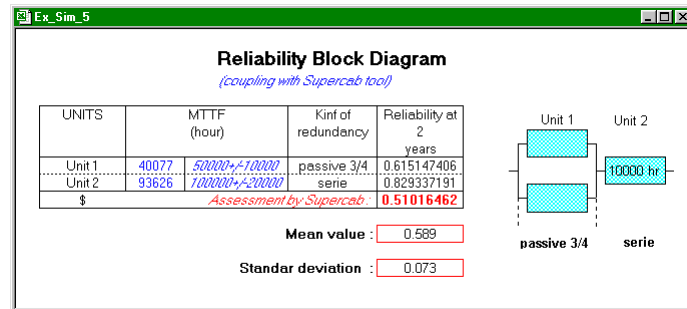
This more complex example shows how the performances and the costs of a constellation of satellites can be simulated by considering various strategies of deployment and renewal.

Also proposed in demonstration by the tool, this example required the development of a specific macro function which makes it possible to identify the nth value in a list:

Order (list, N)

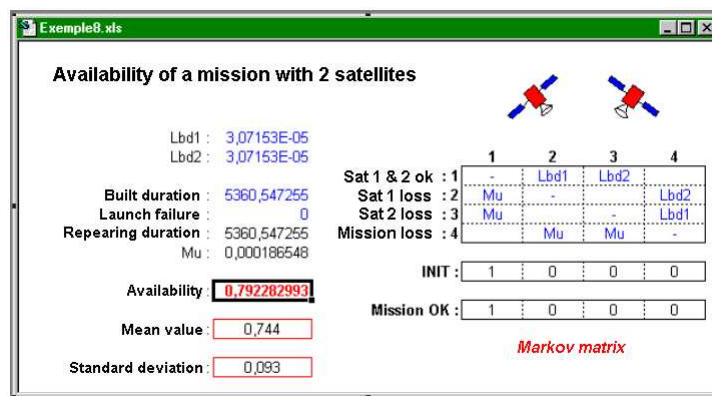
4.3 Joint Application with **SUPERCAB** + Software

SUPERCAB + is a dependability and safety tool. Examples below illustrate the joint-application possibilities offered with such software.



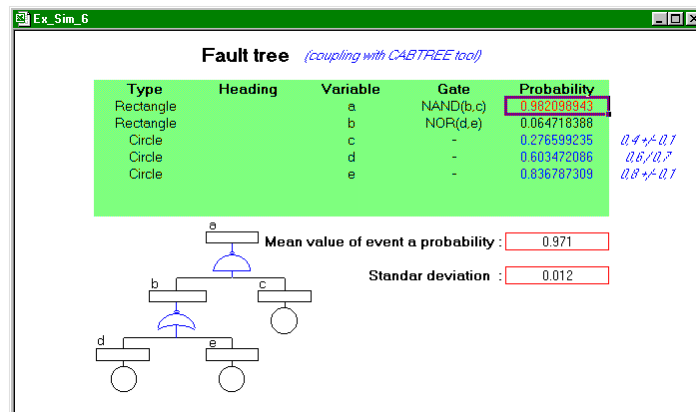
Scattering over the reliability of a system architecture

Example hereof shows how this joint-application helps initiating scattering on entries (MTTF : mean time to failure) of a particularly complex processing (reliability calculation of a system architecture assessed from automatically-generated Markovian models).



Scattering over a mission reliability

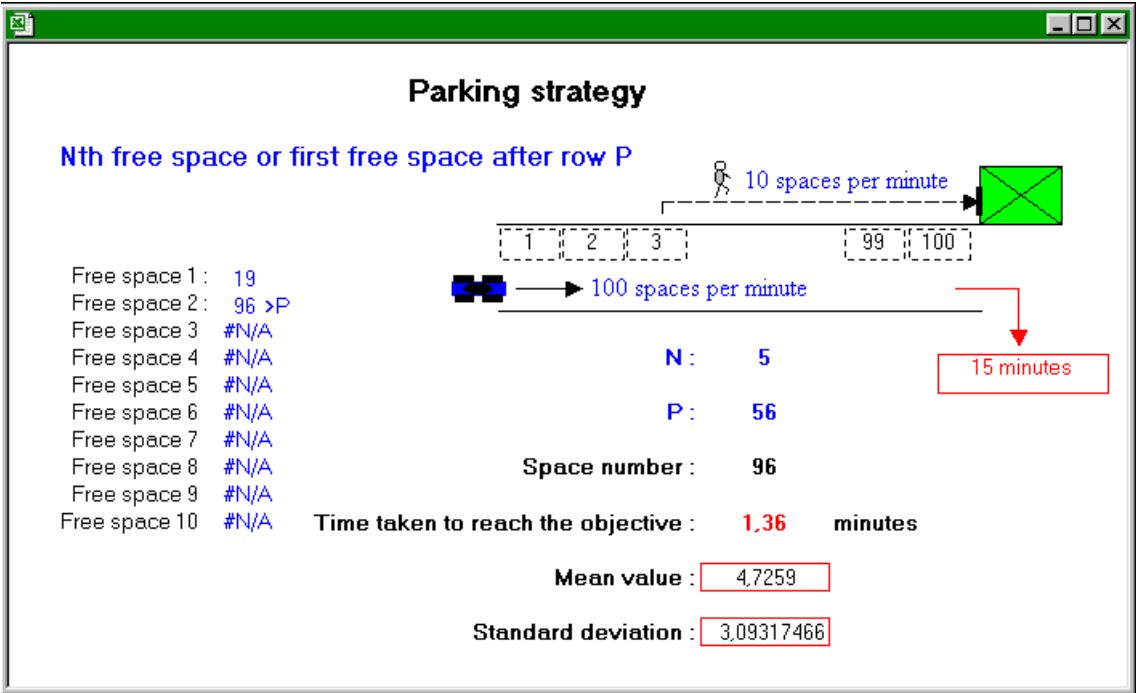
Equally, these last two examples illustrate this joint-application possibility for a Markov matrix processing and an event-probability assessment in a fault tree, respectively.



Scattering on probability of an event

4.4 Joint Application with GENCAB software

Such a coupling enables to achieve optimizations from simulation results.



In this example, the two optimal parameters of parking strategy (Nth free parking lot and row P from which the first free parking lot will be systematically taken) are being searched by **GENCAB** by minimizing the average of times taken to reach the objective, assessed by **SIMCAB**.

This joint-application possibility may help dealing with different types of problems So, it becomes possible optimizing parameters of an intervention strategy on a system subject to simulation (command/control, traffic management, maintenance, ...).

5 Features of Probability Laws

The different software-proposed probability laws are briefly described in this chapter.

Binomial Law :

Binomial law represents the number of successes obtained after n independent tests, each one with a probability p of success and $(1 - p)$ of failure.

Example : number of failing parts in one production batch.

Erlang Law:

The simple Erlang law represents the duration prior to occurrence of a k th Poissonian type event.

Example : Time before a stock runs out.

Exponential Law :

Exponential law represents duration prior to occurrence of an event whose probability of occurrence per unit of time is constant (rate).

Example : Time of equipment proper operation with constant failure rate (electronic equipment not undergoing wear).

Gamma Law:

This is a very general law with two parameters.

If $\text{Beta} = 1$, law is exponential.

If Beta is an integer K , law is the Erlang law.

If $\text{Lambda} = \frac{1}{2}$ and $\text{Beta} = \text{Nu}/2$ with Nu being an integer, law is the K i-two law with Nu degrees of liberty.

Example : Time before a stock runs out.

Geometrical Law :

Geometrical law represents the number of tests until first success occurs; each test being independent with a probability p of success.

Example : number of parts to be achieved before obtaining a proper one.

Hypergeometric Law :

Close to the Binomial law, the Hypergeometric law represents the number of successes obtained after n print runs without any discount.

Example : number of faulty parts in one sample deriving from a batch of which the initial percentage of elements to be discarded is known.

Lognormal Law :

The Lognormal law features a distribution of which the variable logarithm follows a normal law.

Example : Prediction of a selling price of a product sold at auction.

Normal Law :

Normal law represents many natural phenomena featured by a variable likely to deviate symmetrically with respect to an average value with a decreasing probability.

So, the standard deviation corresponds to the average of deviations.

Example : deviation between size of parts achieved and predicted size.

Pareto Law:

The Pareto Law is a power law defined by 2 parameters: the Pareto index K and the minimum value of the variable.

Very used in quality management, it helps to describe a factor more or less decisive (20% of problems generate 80% of the costs ...).

Pearson Law :

The Pearson law or Khi-two law is a continuous law the random variable of which is the sum of squares of ν normal reduced independent variables.

This law is especially used for confidence interval calculations.

Personalized Law (Kaplan-Meyer):

This functionality allows to define any type of statistics law from its distribution function defined on processing sheet.

Defined by a 2-column matrix (values and growing probabilities from 0 to 1), this function may be entered by user or generated directly by software from experimental data by the Kaplan-Meyer method.

Poisson Law :

The Poisson law represents the number of occurrences per unit of time of independent events the rate of which is constant (probability of occurrence per unit of time).

Example : Number of telephone calls transiting on a line.

Triangular Law :

The Triangular law is featured by values taken between two limiters (minimum and maximum) the probability of which decreases linearly depending on distance at a probable value.

Example : Prediction of a product's sale.

Uniform Law :

The Uniform law is featured by equiprobable values taken between two limiters (minimum and maximum).

Example : Frequencies of a random noise.

Weibull Law :

The Weibull law with 2 or 3 parameters may describe many distributions depending on values of its parameters.

Example : Time of proper operation of an equipment with a variable failure rate (mechanical equipment undergoing a wear).

OPERATING LICENCE AGREEMENT
OF SIMCAB SOFTWARE PACKAGE

ARTICLE 1 : SUBJECT

The purpose of this Agreement is to define the conditions in which the CAB INNOVATION Company grants the customer with a non-transferable, non-exclusive and personal right to use the software package referred to as "SIMCAB" and whose features are specified in user's manual.

ARTICLE 2 : SCOPE OF THE OPERATING RIGHT

The customer may use the software package on one single computer and on a second one provided that the second computer does not operate at the same time as the first one. The customer can only have one software package copy maintained in a safe place as a backup copy.

If this license is regarding a performance on site, the customer may install the package software on a server, while scrupulously complying with purchase conditions stated on specific conditions especially defining the maximum number of users authorized to use the software package from their terminal and the maximum number of users authorized to use it simultaneously. The customer is therefore authorized to perform a number of software package documentation copies equal to the maximum number of users allowed to use it..

CAB INNOVATION will be in a position to perform inspections, either itself or through a specialized entity purposefully authorized by CAB INNOVATION, at customer premises to verify if customer has met its requirements : number of software package copies used, location of such copies, etc... Parties will agree as regards the practical modalities of performance of such inspections so as to disturb minimally customer's activity.

ARTICLE 3 : DELIVERY, INSTALLATION AND RECEPTION

The software package and attached supplies will be delivered to the customer on mail reception date. The customer installs, at its own costs, the software package using relevant manual delivered by CAB INNOVATION. The customer performs the inventory and shall inform CAB INNOVATION, within three working days of the delivery, of any apparent nonconformity with respect to the order. The customer is liable for any loss or any damage caused to supplies as from the delivery.

ARTICLE 4 : TESTING AND GUARANTEE

Guarantee is effective as from the mail delivery date set forth in Article 3 and has a three-month validity. During the guarantee validity, if the customer experiences a software package operation trouble, he should inform CAB INNOVATION about it, so as to receive any helpful explanations with the purpose of remedying such trouble. If the trouble is continuing, the customer will return the C.D. ROM to CAB INNOVATION, at CAB INNOVATION's Head Office, at his own expense and with registered mail with acknowledgement of receipt, by specifying exactly the troubles encountered.

Within the three months of reception of consignment set forth in preceding paragraph, CAB INNOVATION will deliver, at its own expense, a new product version to the customer. This new version will be benefiting of the same guarantee as benefited the first version.

The customer loses the benefit of the guarantee if he does not comply with the instructions manual recommendations, if he performs modifications of configuration set forth in Article 2 above without obtaining a prior written consent from CAB INNOVATION, or if he performs modifications, additions, corrections, etc... on software package, even with the support from a specialized service company, without obtaining a prior written consent from CAB INNOVATION.

ARTICLE 5 : PROPERTY RIGHT

CAB INNOVATION declares to be holding all the rights provided for by the intellectual property code for SIMCAB package software and its documentation.

As this operating-right granting generates no property-right transfer, the customer abstains from :

- any SIMCAB software package reproduction, whether it is wholly or partly carried out, whatever the form assumed, excepting the number of copies authorized in Article 2 ;
- any SIMCAB software package transcription in any other language than that provided for in this Agreement (see Appendix), any adaptation to use it in other equipment or with other basic software packages de base than those provided for in this Agreement.

To ensure this property protection, the customer undertakes especially to

- maintain clearly visible any property and copyright specifications that CAB INNOVATION would have affixed on programs, supporting material and documentation ;
- assume with respect to his staff and any external person any helpful information and prevention step.

ARTICLE 6 : USING SOURCES

Any SIMCAB software package modification, transcription and, as a general rule, any operation requiring the use of sources and their documentation are exclusively reserved for CAB INNOVATION.

The customer holds the right to get the information required for the software package interoperability with other softwares he is using, under the conditions provided for in the intellectual property code.

In each case, an amendment of these provisions will set out the price, time limits and general terms of performance thereof.

ARTICLE 7 : LIABILITY

The customer is liable for :

- choosing SIMCAB software package, its adequacy with his requirements, precautions to be assumed and back-up files to be made for his operation, his staff qualification, as he received from CAB INNOVATION recommendations and information required upon its operating conditions and limits of its performances set forth in user's manual;
- the use made for results he obtains.

CAB INNOVATION is liable for the software package conformity with his documentation. The customer shall prove any possible non-conformity.

CAB INNOVATION does not assume any whatsoever guarantee, whether explicit or implicit, relating to the software package, manuals, attached documentation or any supporting item or material provided and, especially, any guarantee for marketing of any products relating to software package or for using software package for a determined use, any guarantee for absence of forgery, etc...

Under no circumstances CAB INNOVATION could be held responsible for any whatsoever damage, especially loss in performance, data loss or any other financial loss resulting from the use or impossibility to use the SIMCAB software package, even if CAB INNOVATION was told about the possibility of such damage.

In the event where CAB INNOVATION liability is retained, it is expressly agreed upon that the total amount of compensation to be paid by CAB INNOVATION, all cases taken together, could not in any way exceed the initial-royalty price reduced by 25 % per period of twelve months elapsed as from the mailing delivery date.

ARTICLE 8 : DURATION

This Agreement is entered into for an undetermined period of time as of the date set forth in Article 3.

ARTICLE 9 : TERMINATION

Each party may terminate this Agreement, by registered mail with acknowledgement of receipt forwarded to the other party, for any breach by such party of its obligations, despite a notice remaining unresponsive for 15 days, and this occurring with no prejudice to damages it could claim and provided that the last paragraph of Article 7 above, be enforced.

At end of this Agreement or in case of termination for whatsoever reason, the customer will have to stop using SIMCAB software package, pay all sums remaining due on date of termination and return all elements composing the software package (computer programs, documentation, etc ...) without maintaining any copy of it.

ARTICLE 10 : ROYALTY

As a payment for the operating-right concession, the customer pays CAB INNOVATION an initial royalty the amount of which is determined in specific conditions.

ARTICLE 11 : PROHIBITED TRAFER

The customer refrains from transferring the software package operating right granted personally to him by these provisions. The customer also abstains from making documentation and supporting material (CD ROM), even free of charge, available to a person not expressly set forth in second paragraph of Article 2.

ARTICLE 12 : ADDITIONAL SERVICES

Any additional services will be subject to an amendment of these provisions, possibly through an exchange of letters, so as to specify the contents, modalities of achievement and the price.

ARTICLE 13 : CORRECTIVE AND PREVENTIVE MAINTENANCE

The corrective and preventive maintenance may be subject, upon customer's request, to a separate Agreement attached to these provisions.

ARTICLE 14 : ENTIRETY OF THE AGREEMENT

The user's manual defining the SIMCAB software package features is appended to these provisions.

The provisions of this Agreement and his Appendix express the entirety of the Agreement entered into between the parties. They are prevailing among any proposition, exchange of letters preceding its signing up, together with any other provision stated in documents exchanged between the parties and relating to the Agreement's subject matter.

If any whatsoever clause of this Agreement is null and void with respect to a rule of Law or a Law in force, it will considered as not being written though not involving the Agreement's nullity.

ARTICLE 15 : ADVERTISING

CAB INNOVATION could mention the customer in its business references as a SIMCAB software package user.

ARTICLE 16 : CONFIDENTIALITY

Each party undertakes not to disclose any kind of documents or information about the other party that it would have been informed of on the Agreement's performance and undertakes to have such obligation fulfilled by the persons it is liable for

ARTICLE 17 : AGREEMENT'S LANGUAGE

This Agreement is entered into and drawn up in the French language.

In the event where it is translated into one or more foreign languages, only the French text will be deemed authentic in case of any dispute between the parties.

ARTICLE 18 : APPLICABLE LAW - DISPUTES

The French Law governs this Agreement.

In the event of any disagreement over the interpretation and performance of any whatsoever provision of this Agreement, and if parties fail to reach an agreement under an arbitration procedure, only Toulouse's Courts will be competent to settle the dispute, despite the plurality of defendants or the appeal for guarantee.