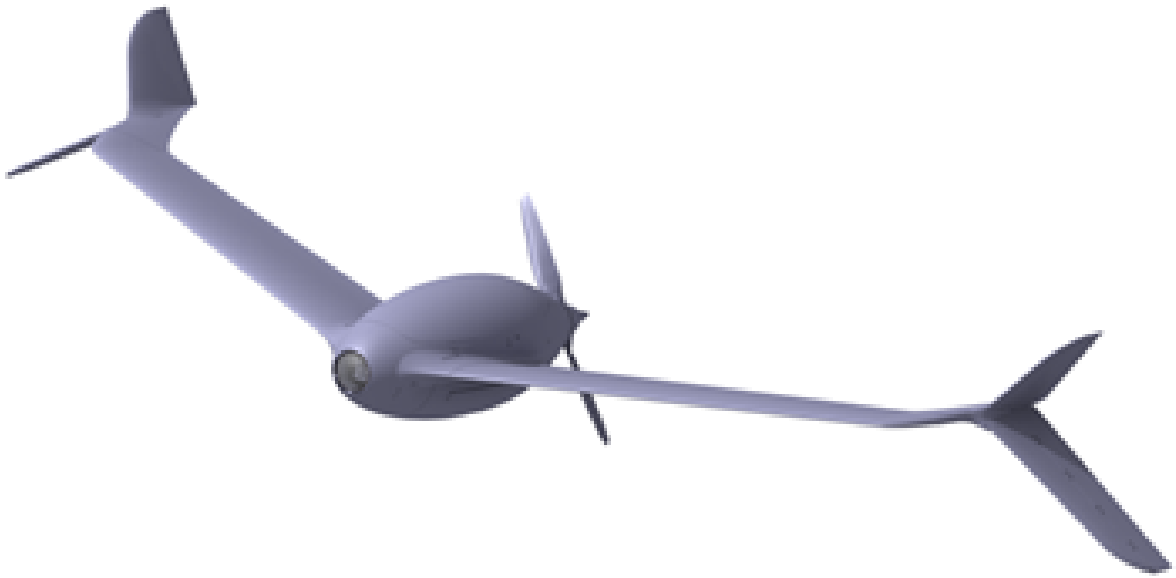
Cab Designer Version 2

Using Microsoft EXCEL®



Hybrid optimisation and Monte Carlo simulation

User's Manual

CAB INNOVATION
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FOREWORD

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Contents

1 Cab Designer software

1.1 General Presentation

Cab Designer software provides designers with powerful optimisation and simulation capability in Excel or any other Windows-based tool, via a command prompt.

The hybrid optimisation algorithm combines global (Genetic Algorithms) and local (Simplex or Nelder-Mead) methods in order to efficiently find the optimal solution from any configuration of variables, without getting stuck on a local optimum.

It deals with variables of real, integer, binary, alphanumeric, permutation, combination with or without repetition and arrangement types.

It manages possible constraints, by accepting or prohibiting their temporary violation by the penalty or interior point method.

It covers all types of optimisation problems including the adjustment of probabilistic models using the maximum likelihood method (accelerated reliability or degradation models in particular). It then calculates the Fischer matrix in order to be able to estimate asymptotic confidence intervals by the WALD method.

Monte Carlo simulation makes it possible to characterize the dispersions generated by random variables in the calculation results.

Random variables can be defined according to various probability laws: Beta, Binomial, Chi square, Erlang, Exponential, Gamma, Geometric, Gumbel, Hypergeometric, Lognormal, Normal, Normal Standard, Pareto, Pearson, Poisson, Student, Triangular, Uniform, Gamma Variance, Weibull.

The requested results are in the form of mean, standard deviation, quantiles, probability of exceeding a threshold, with the associated distribution curves.

Optimisation can focus on a simulation result, such as a mean value or a quantile Qα, with a probability α of not being exceeded.

When optimization focuses on a mean value, computational time can be significantly reduced by roughly evaluating candidates in a small number of simulations, then more precisely through additional simulations, depending on the results obtained.

Cab Designer does not require any special knowledge of mathematics, beyond basic notions, and can be used in any field of engineering.

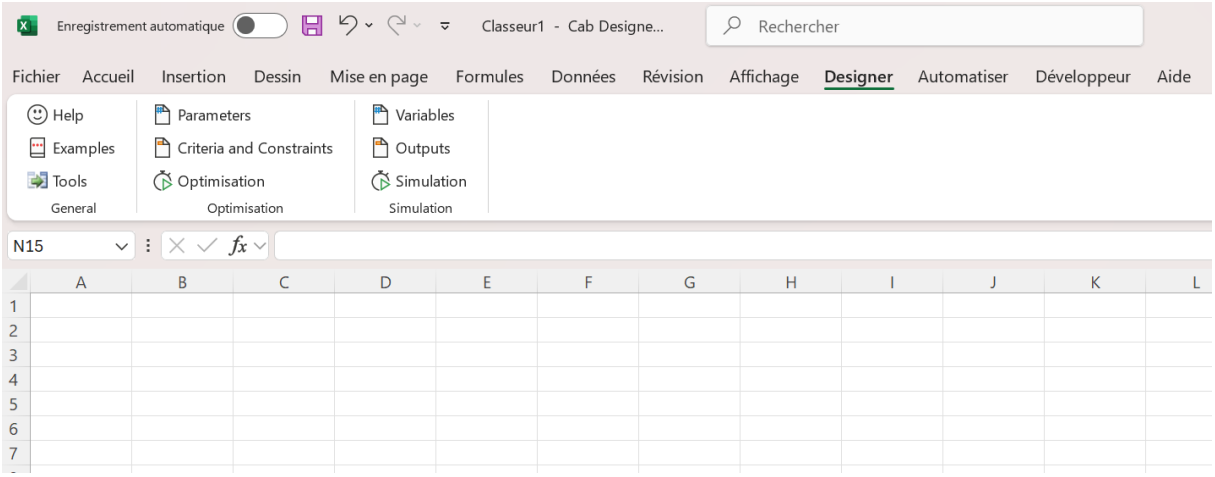
1.2 INSTALLING GENCAB ON HARD DISK

Please follow instructions shown in manual.

1.3 STARTING CAB DESIGNER

In EXCEL, open Designer.xlam file.

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



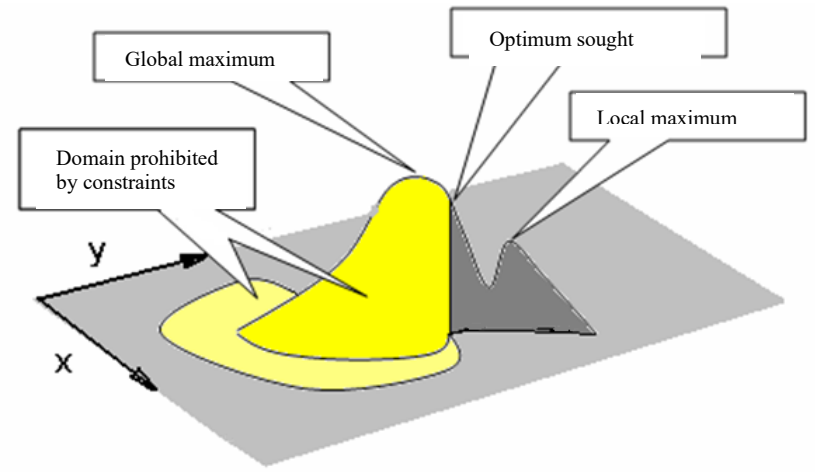
Three submenus are then offered:

- a general menu including help, allowing in particular to obtain the user manual, application examples and a button to access different tools.a menu specific to optimisation.
- a menu specific to the simulation.

2 Optimisation

2.1 Principle of optimisation

As illustrated in the following figure, parametric optimisation seeks to find the maximum or minimum of a function whose decision variables can be subject to constraints which limit the range of variation.



The function can have several local optima and a global optimum.

In addition to the performance function f(x, y…), which constitutes the criterion to minimize or maximize, the different constraints can be expressed by as many inequalities of the form Ci(x, y…) ≥ 0.

Variables can be of various types (real, integer, binary, alphanumeric, etc.).

An alphanumeric variable can thus be used to name a class of objects and be able to access a catalog of properties in a database.

2.2 Initializing parameters

The "Parameters" command from the "Optimisation" menu allows you to create a table, named "DATA", in the active sheet in which the user enters the characteristics of the parameters of the function to be optimized.

The following table thus defines five parameters whose name is indicated in the first line, the type in the second, the variation range or values k and n, in the two following columns.

The initial value of the parameters can be indicated in the fifth column.

DATA	1	2	3	4	5
Name	Par_1	Par_2	Par_3	Par_4	Par_5
Type	Real	Binary	Alphanumeric	Combination	Permutation
Min / k	1		7	2	
Max / n	10			5	
Init / End					

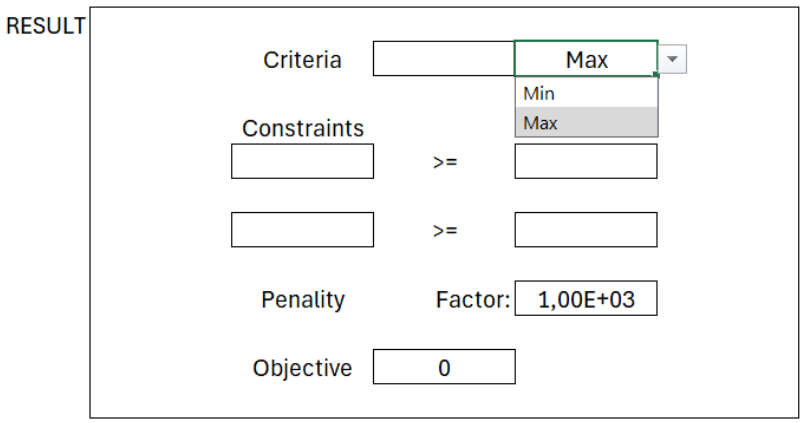
Real
Integer
Binary
Alphanumeric
Permutation
Combination
Repetition
Arrangement

Eight types of parameters are offered via a drop-down menu:

- Real between min and max values,
- Integer between min and max values,
- Binary (0 or 1),
- Alphanumeric (one value among k from 1 to 9),
- Permutation (values from 1 to k differently ordered),
- Combination (k values chosen from n from 1 to 9 without repetition),
- Repetition (k values chosen from n with possible repetition),
- Arrangement (k values chosen from n ordered and without repetition).
-

2.2 Definition of the criterion and constraints

The "Criteria and Constraints" command from the "Optimisation" menu allows you to create a table, named "RESULT", in the active sheet in which the user enters a calculation result, specifying whether this result must be maximized or minimized by means of from a drop-down menu.

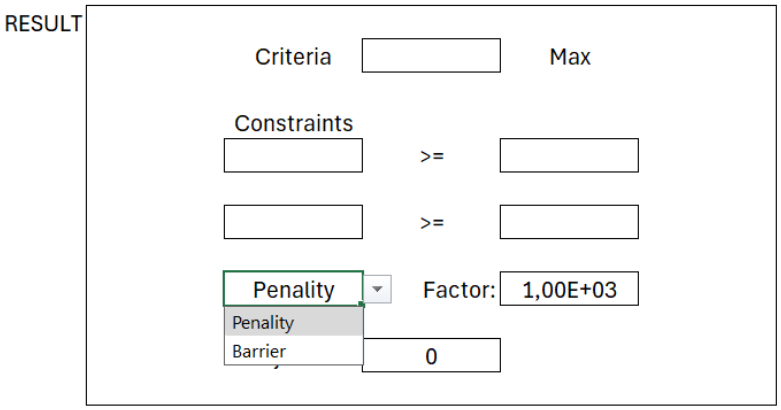


The table allows you to define as many optimisation constraints as you want in the form of inequality between two cells.

The performance function is then entered into the "Objective" cell based on the criteria and constraints, as in the example below.

=IF(F4="Max";1;-1)*E4+F11*IF(D11="Penality";-SUM(MAX(0;F7-D7);MAX(0;F9-D9));SUM(IF(D7>F7;LOG(D7-F7);-10^9);IF(D9>F9;LOG(D9-F9);-10^9)))

A drop-down menu allows you to indicate whether the violation of constraints is temporarily authorized (penalty: penalty method) or prohibited (barrier: interior point method).



A factor (from 0 to 10^{15}) allows you to adjust the intensity of the penalty or the barrier function as follows:

Penalty method::

Violation = $^{Nb\_constraints}_{0} \sum \min(0, Value - Threshold)$

Performance = if (Maximum, 1, -1) * Criterion + Factor * Violation * Loop number / Optimisation loop number

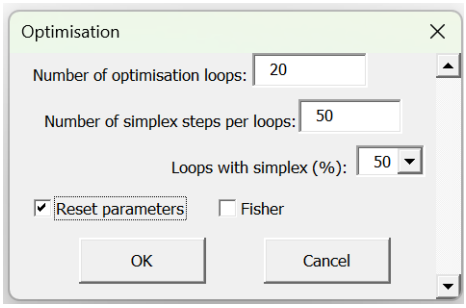
Interior point method:

Fonction barrière = $^{Nb\_constraints}_{0} \sum$ if(Value > Threshold, Log(Value – Threshold), -10^9)

Performance = if (Maximum, 1, -1) * Criterion + Factor * Barrier function

2.3 Start of optimisation

The "Optimisation" command in the "Optimisation" menu allows you to launch the optimisation after having indicated the number of optimisation loops chosen (Genetic Algorithms) as well as that of simplex steps carried out at the end of certain loops, playing only on the real parameters only.



The simplex may only be performed on a certain percentage of optimization loops.

The value of the parameters can be reset at startup (Reset) or taken from the previous calculation, entered in the “Init/End” cell.

The Fischer matrix can be calculated after fitting a probabilistic model by the maximum likelihood method ({=Fisher_matrix}).

Many application examples are provided by the "Examples" command in the "General" menu.

Thus, the following mathematical function has many local optima.

Mathematical function

Function: $MAX(0,02;\sin(x)\times\sin(y)/(100+(x^2\times y^2)^{0,5})$

Constraint: $x >= -0,3 \times y^2$

DATA	1	2
Name	x	y
Type	Real	Real
Min / k	-10	-10
Max / n	10	10
Init / End	1,5364536	1,53645356

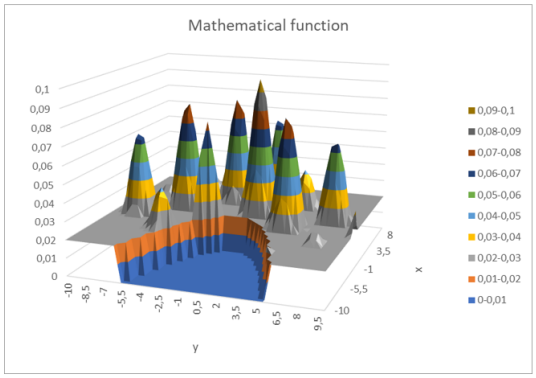
RESULT

Criteria 0,09721014 Max

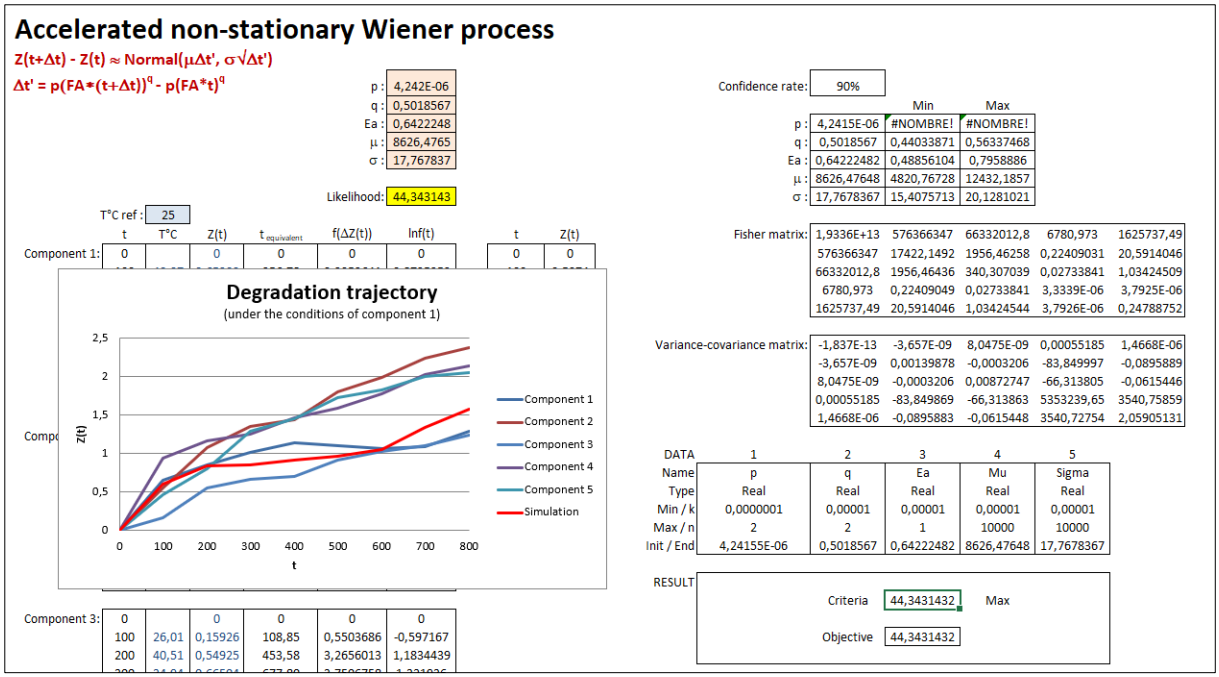
Constraints 1,5364536 >= -0,7082069

Penality Factor: 1,00E+03

Objective 0,09721014



The following example concerns the fitting of a degradation model by the maximum likelihood method from wear trajectories of the same type of component.

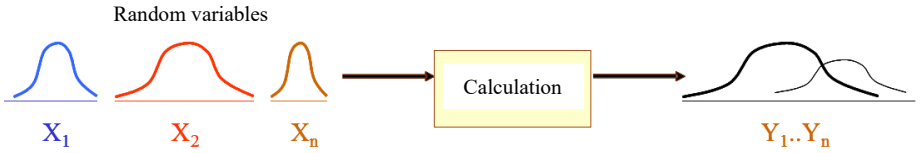


The Fischer matrix makes it possible to estimate asymptotic confidence intervals surrounding the 5 parameters of the probabilistic model, by applying the WALD method.

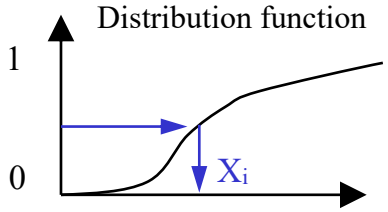
3 Simulation

3.1 Principle of Monte-Carlo simulation

Illustrated by the following figure, Monte Carlo simulation consists of simulating a configuration of random variables used in a calculation to obtain a result, then repeating the operation a large number of times in order to obtain a distribution of the result. The calculation can be of any complexity and lead to multiple results.



Each of the random variables is simulated by randomly drawing a value between 0 and 1, then applying the reciprocal of the distribution function (or 1 - F(x)), when it exists, as illustrated in the following figure.



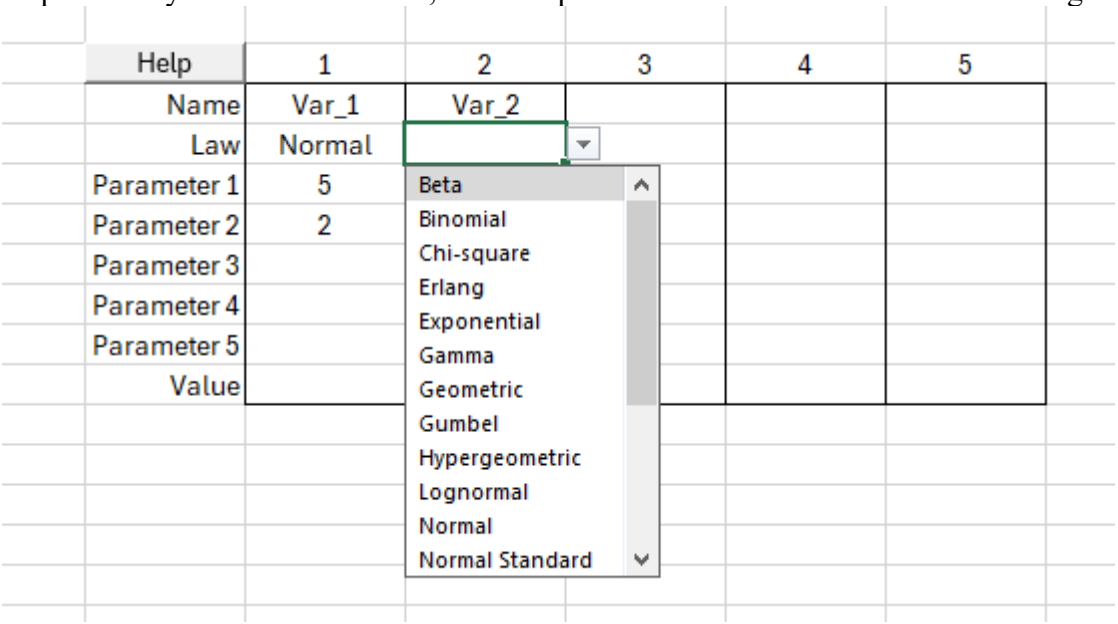
For example, the operating time of a component not subject to wear is simulated by applying the reciprocal function of the exponential law to a random value between 0 and 1, i.e.:

$$TTF = -LN(RAND())/\lambda$$

3.2 Initialization of random variables

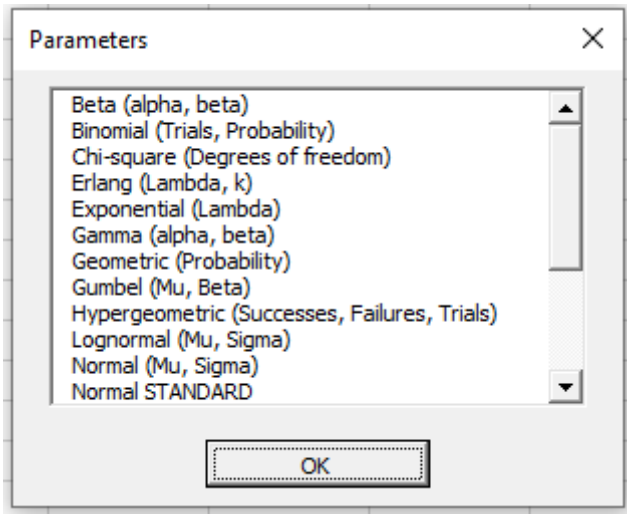
The "Variables" command from the "Simulation" menu allows you to create a table, named "RANDOM", in the active sheet in which the user enters the characteristics of the random variables.

The following table thus defines 5 variables whose name is indicated in the first row, the type of probability law in the second, and the parameters of the laws in the following columns.



Twenty laws are offered via a drop-down menu. These laws are, moreover, the subject of complementary calculation functions accessible with those of the spreadsheet.

The “Help” button allows you to display the nature of the parameters of the different laws:



3.3 Definition of expected results

The "Outputs" command from the "Simulation" menu allows you to create a table, named "SIMULATION_RESULTS", in the active sheet in which the user enters the characteristics of the expected results.

The table below thus defines three results whose name is indicated in the first line, the possible provision of a graph in the second, and the type of expected result in the third.

RESULTS	1	2	3
Name	Var_1	Result_1	Result2
Chart	Yes	No	No
Output		Quantile	
Parameter		90	
Value			

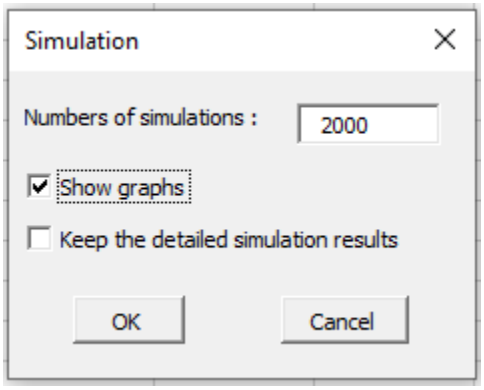
Average
Standard deviation
Quantile
>
<

A drop-down menu allows you to choose the type of expected result: average value, quantile standard deviation or probability of exceeding or not exceeding a threshold.

The type of quantile (Q90) or the threshold value must be entered in the “Parameter” line.

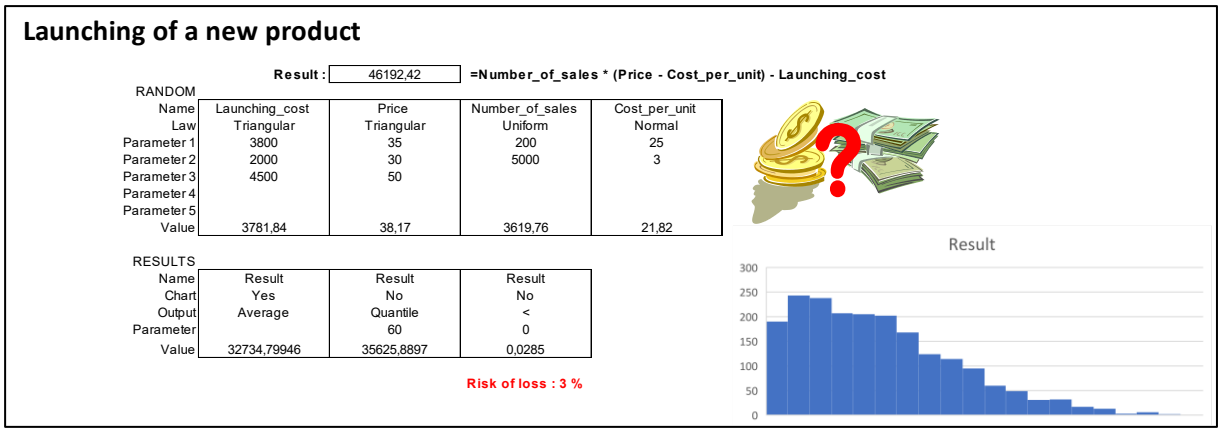
3.4 Launching the simulation

The "Simulation" command from the "Simulation" menu allows you to launch the simulation, after indicating the chosen number of simulations.



Check boxes allow you to display the graphs or keep the detailed results at the end of the simulations.

For illustration purposes, the following example is one of the application examples offered by the “Examples” command in the “General” menu.



Formulas for simulating random variables are then entered in the "Value" column of the "RANDOM" table.

Likewise, the results requested in the "Output" column of the "SIMULATION_RESULTS" table are entered in the "Value" column of this same table.

The corresponding cells then have the name of the variable to which the chosen type of result is added, as in the following examples:

Var_1_Average

Result_1_Standard_deviation

Result_2_Quantile

Result_below_threshold

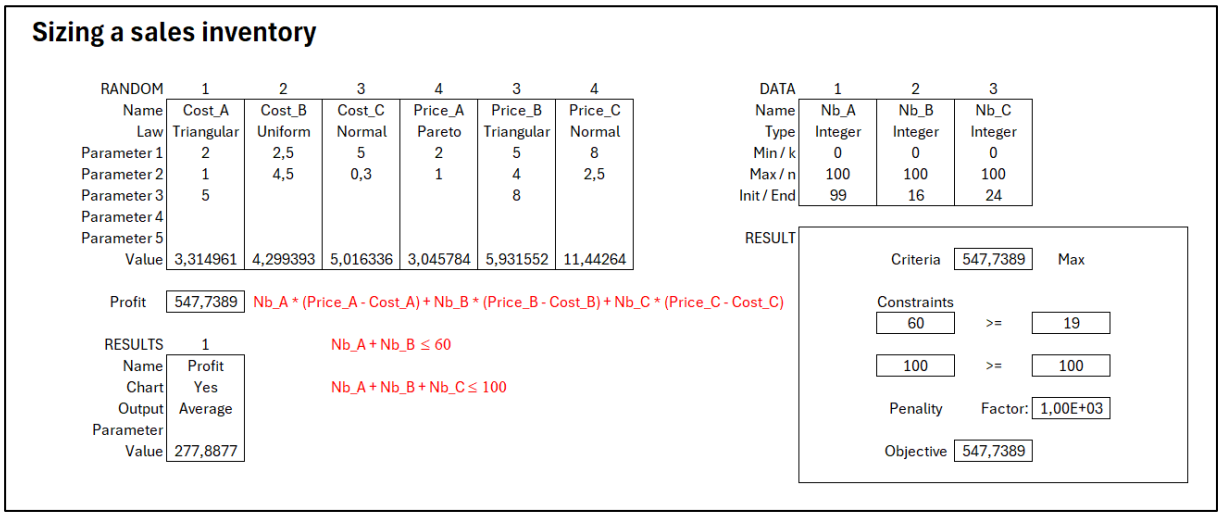
4 Coupling between optimisation and simulation

The optimisation can relate to a simulation result, such as an average value or a quantile Qα having a probability α of not being exceeded.

When a simulation is launched, the name “Monte_Carlo_Simulation = true” is created in the corresponding file.

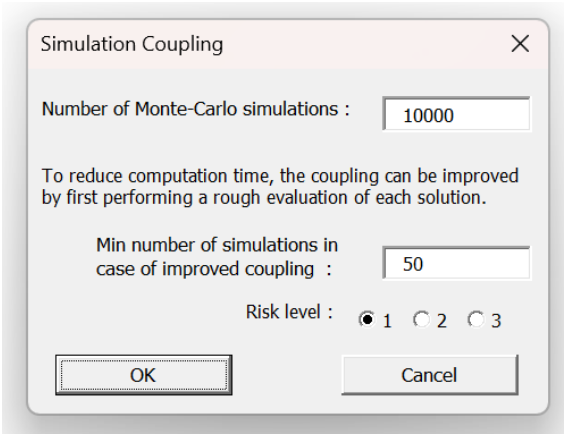
If this same file is used for optimisation, the software detects it and asks the user if they wish to be coupled with the simulation and, if so, with what number of simulations per evaluation.

For illustration purposes, the following example is one of the application examples offered by the “Examples” command in the “General” menu.



This example focuses on optimizing an inventory of three product types, whose procurement cost and selling price are random variables governed by different probability distributions.

The expected profit is the optimization criterion, and the number of products in stock is subject to two constraints.



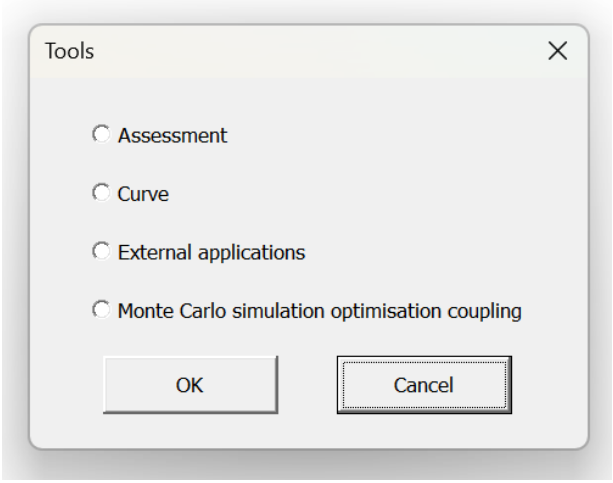
The user is asked at the beginning of the process to specify the number of simulations to be performed per assessment.

In the case of optimization on an average value, the user can also enter a minimum number of simulations and a level of risk of inappropriate rejection of candidates if he wishes to use an optimized coupling algorithm.

This allows the optimization time to be divided by a number ranging from 15 to 60, depending on the problem being addressed and the chosen risk level, in the case of rough assessments of 50 simulations followed by assessments of up to 10,000 simulations.

5 Additional Tools

The "Tools" command in the "General" menu provides access to various tools.

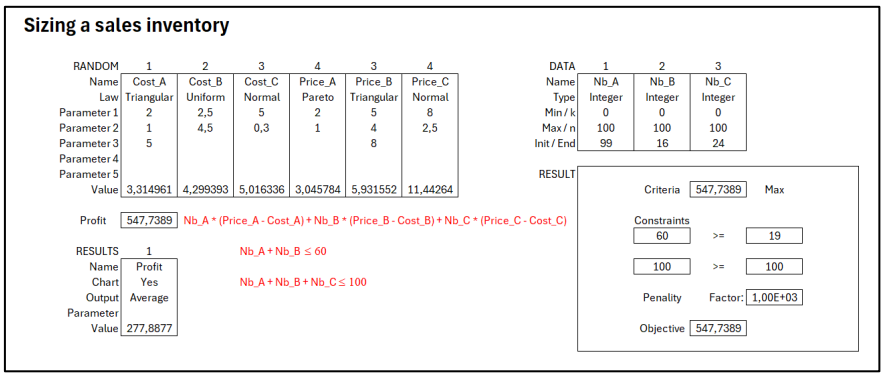


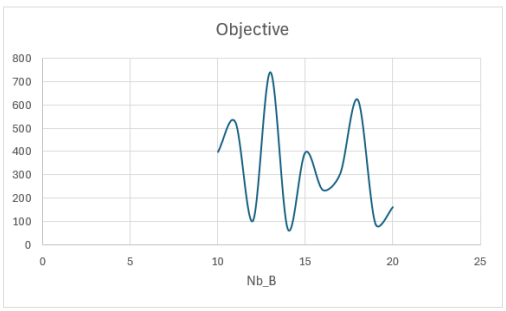
5.1 ASSESSMENT

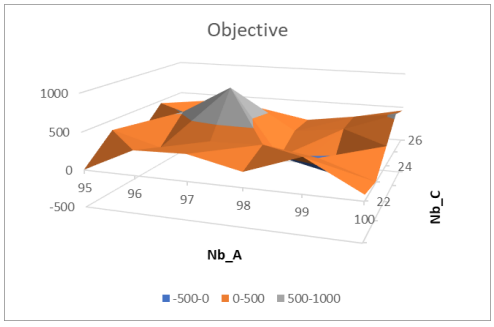
The "Assessment" option allows you to evaluate a parameter configuration in an optimization file by calculation or simulation.

5.2 2D / 3D CURVE

The “Curve” option allows you to plot a 2D or 3D curve of the performance function (Objective) as a function of one or two real or integer parameters.







5.3 Interface with external application

The “External application” option allows you to create a control interface for external applications running under Windows, such as the GRIF software suite (from Total) to ensure the best availability of a system based on operating costs, or the free Xfoil software to optimize the aerodynamic performance of a profile.

The name: External_Application = 1 is then created in the calculation file.

This functionality allows you to run applications external to the Excel environment and retrieve the results during an optimisation or simulation.

It consists of writing or reading text files (.txt, .dat, .bat, etc.), launching files (.bat), executing workbook calculations or waiting a certain duration between actions.

These actions are each the subject of a specific column in an interface file and are processed sequentially in the order of the column numbers.

The type of action to be performed is entered in the first line of the corresponding column, either “Write”, “Read”, “Launch”, “Wait” or “Calculation”.

The "LaunchWait" action allows you to launch an external application and wait until it finishes running.

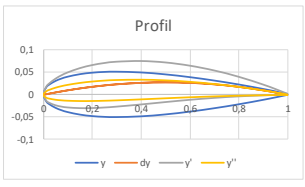
The name of the file to be processed, with its directory path, is entered in the second line of the corresponding column.

This second line is used to define the waiting time (in seconds) for the “Wait” action and the calculation domain to be executed for the “Calculation” action: “Active” for the active worksheet or “All » for the entire workbook.

The following lines will be copied, line by line, from the first line of the text file, during the “Write” action, or used to receive data from the text file, line by line, during the “Read” action. ".

For illustration purposes, the following example is one of the application examples offered by the “Examples” command in the “General” menu.

Calculation	Write	Write	Write	Write	Launch	Wait	Read	Calculation
All	C:\xfoil\Profil.dat	C:\xfoil\commands.bat	C:\xfoil\xfoil.bat	C:\xfoil\result.txt	C:\xfoil\xfoil.bat	5	C:\xfoil\result.txt	All
		LOAD C:\xfoil\profil.dat	del C:\xfoil\result.txt					
	1 0.00046242469373101	oper	C:\xfoil\xfoil.exe < C:\xfoil\commands.bat				XFOIL Version 6.99	
	0.95 0.00520122789494036	visc80000						
	0.9 0.00956106242194309	0					Calculated polar for:	
	0.8 0.01717294385928 66	iter						
	0.7 0.0233378506000102	100					1 1 Reynolds number fixed Mach number fixed	
	0.6 0.0280502018080061	pacc						
	0.5 0.0312018239078455	C:\xfoil\result.txt					xtrf = 1.000 (top) 1.000 (bottom)	
	0.4 0.032603984030081						Mach = 0.000 Re = 0.080 e 6 Ncrit = 9.000	
	0.3 0.0319213337245982	CI 0.5						
	0.25 0.0306435112938461	quit					alpha CL CD CDp CM Top_Xtr Bot_Xtr	
	0.2 0.0286014398614958						------ -------- --------- --------- -------- -------- --------	
	0.15 0.0256317256484147						3.957 0.5000 0.02226 0.01095 -0.0256 0.0515 1.0000	
	0.1 0.0214299628943723		Xfoil address : https://web.mit.edu/drela/Public/web/xfoil/					
	0.075 0.0186874111126561							
	0.05 0.0152864902629786							
	0.025 0.0107426659450749							



This example seeks to minimize the drag coefficient (CD) of a profile having a certain lift coefficient (CL = 0.5) by playing on two parameters, from the standard symmetrical profile Naca 0010.

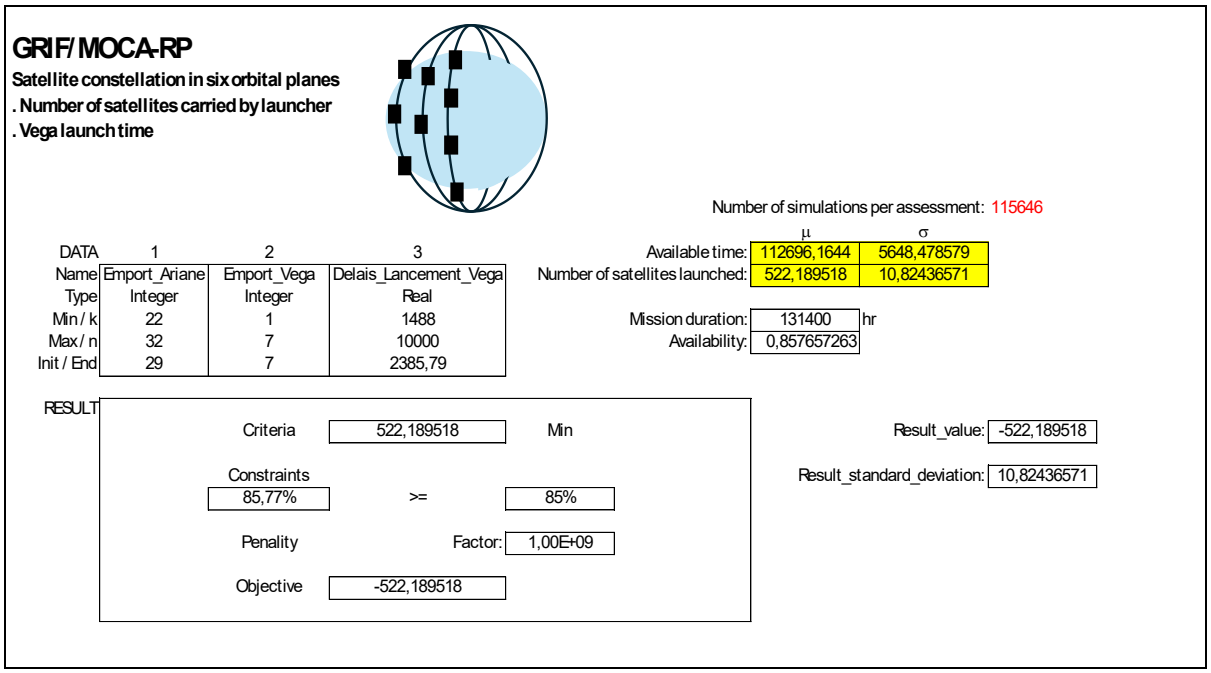
The first parameter modifies the relative thickness of the profile and the second its curvature.

The xfoil aerodynamic simulation software can thus be coupled to Cab Designer. The simulation results are obtained for a profile type and a Reynol number of 80,000 at angles of incidence varying from 0 to 10°, with a step of 0.5°.

Available at web.mit.edu/drela/Public/web/xfoil/, the xfoil.exe, pplot.exe and pxplot.exe files must first be saved in the "C:\xfoil" directory.

The "External interfaces" button in the "Tools" menu allows you to declare a workbook as an external interface (by creating the variable External_Interface = True), so that it can be controlled by optimisation or simulation tools to evaluate solutions.

In the case of an external application performing Monte Carlo simulations, such as Total's GRIF/Moca RP software, the result of the evaluation must be given to a parameter named "Result_value" in the spreadsheet, as in the following example accessible via the "Examples" menu.



This example deals with the deployment and renewal of a constellation of satellites placed on 6 orbital planes. The optimization focuses on the number of satellites on board per launcher and the launch time allowing to minimize the consumption of satellites in orbit while ensuring a service availability greater than 85%, with at least 21 operational satellites on each of the orbital planes.

5.4 Coupling with Monte-Carlo simulation

The "Monte Carlo Simulation Optimisation Coupling" option allows you to define a calculation file as a simulation file by creating the name: Optimisation_Simulation_Coupling = 1.

This option is particularly used with interface files for external applications.

OPERATING LICENCE AGREEMENT

OF CAB DESIGNER 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 "CAB DESIGNER" 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 looses 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 CAB DESIGNER package software and its documentation.

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

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 CAB DESIGNER 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 CAB DESIGNER 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.