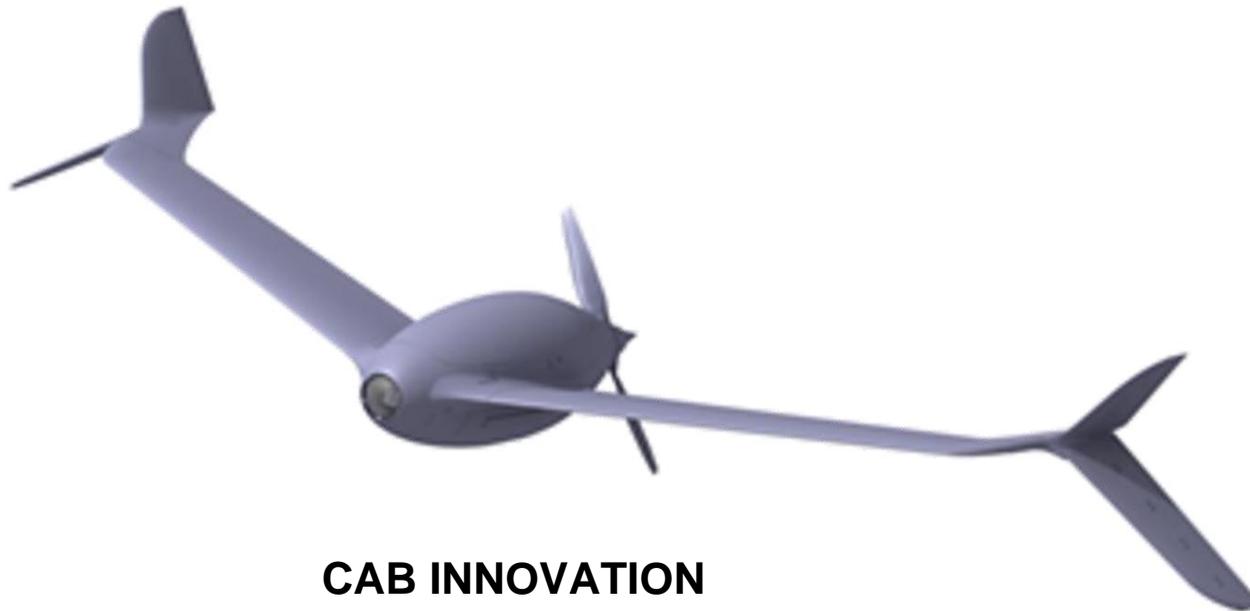# Optimization and simulation software *Cab Designer V.2*
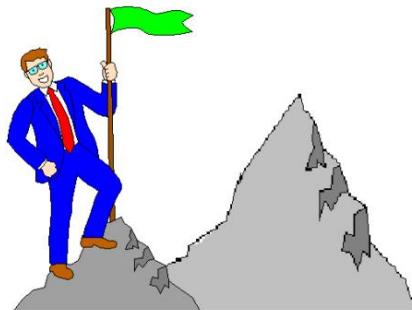
CAB INNOVATION

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Contact@cabinnovation.com

Introduction

ÿ Cab Designer is an improvement and innovation software that puts the most effective optimization and simulation techniques within everyone's reach.

- What is optimization?

- Cab Designer software

- Examples of applications in different themes

Optimization

ÿ Optimization is the search for the best solution in all
the areas

ÿ But it is not:

- choose the first solution that meets the specifications •
choose between several solutions
- carry out a sensitivity analysis on some parameters

Optimization

Ÿ This decision aid:

- is not reserved for high-flying mathematicians

- constitutes a basic tool for engineers and analysts who are best able to correctly formalize concrete problems

- requires high-performance tools accessible to non- specialists

- is little and poorly taught in schools and universities

Optimization

Ÿ **Performance function**
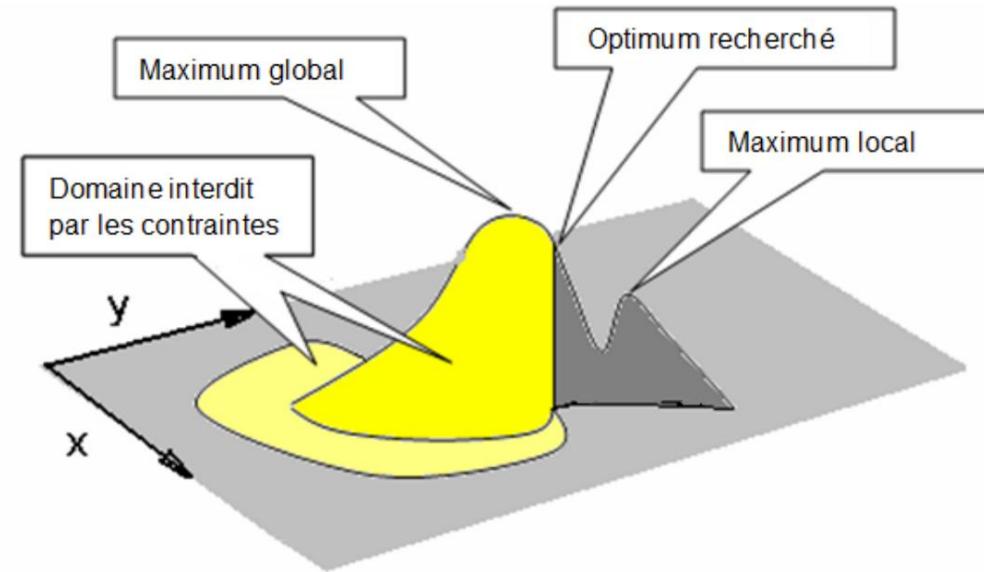
Ÿ Optimization is parametric when a performance function can be defined from various

decision variables

Ÿ **It can have a global optimum and several local optima**

Ÿ Variables may be subject to constraints which limit their range of variation

Optimization

ÿ Formulating a problem consists of

- identify the decision variables: x, y… • choose

  an optimization criterion (or a combination of criteria) in the form of a
  performance function: f(x, y…)

- express possible constraints in the form of as many
  of inequalities prohibiting certain configurations of the decision
 variables: Ci(x, y…) ÿ 0

ÿ A problem can be treated differently depending on the choice of criteria and
constraints:

- maintain performance at the lowest cost
- seek the best performance within a cost envelope

Optimization

ÿ The constraints are then aggregated to the performance function by various methods which allow or not the transient crossing of the constraint domain

Pénalité

$$f(x, y, \cdots) \pm P \times \Sigma \ \Delta Ci^2$$

Point intérieur

$$f(x, y, ...) \pm -\ln(\min(\delta Ci))$$
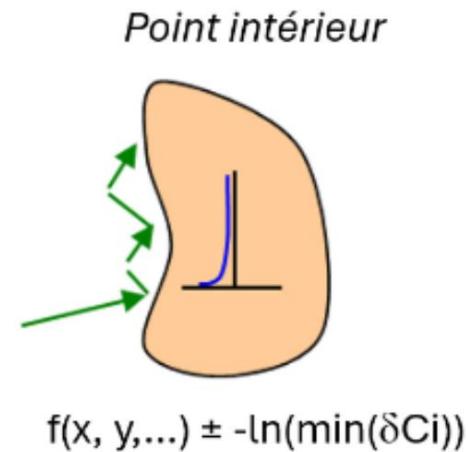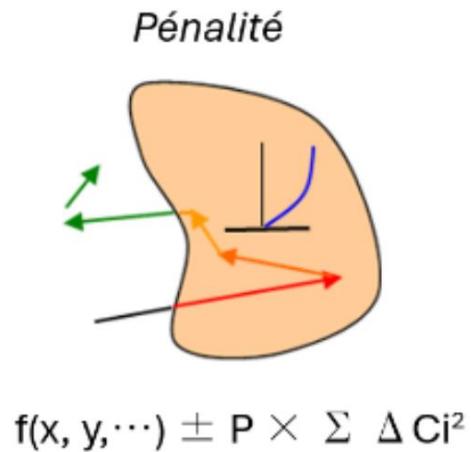
Optimization

Ÿ A plethora of optimization methods exist:

- *cancellation and change of sign of the derivative of a function derivable,*

- *displacement in the direction of maximum slope (gradient method),*

- *branch and bound tree search to solve combinatorial problems,*

- *algorithms specific to typical problems such as the shortest path (traveling salesman) or best filling (backpack),*

- *dynamic programming adapted to process management or*

    inventory management, etc.

Ÿ But besides planning and scheduling, industrial issues are of the black box type, only giving access to the result of the evaluation of the configurations of decision variables

Optimization

Fonction mathématique
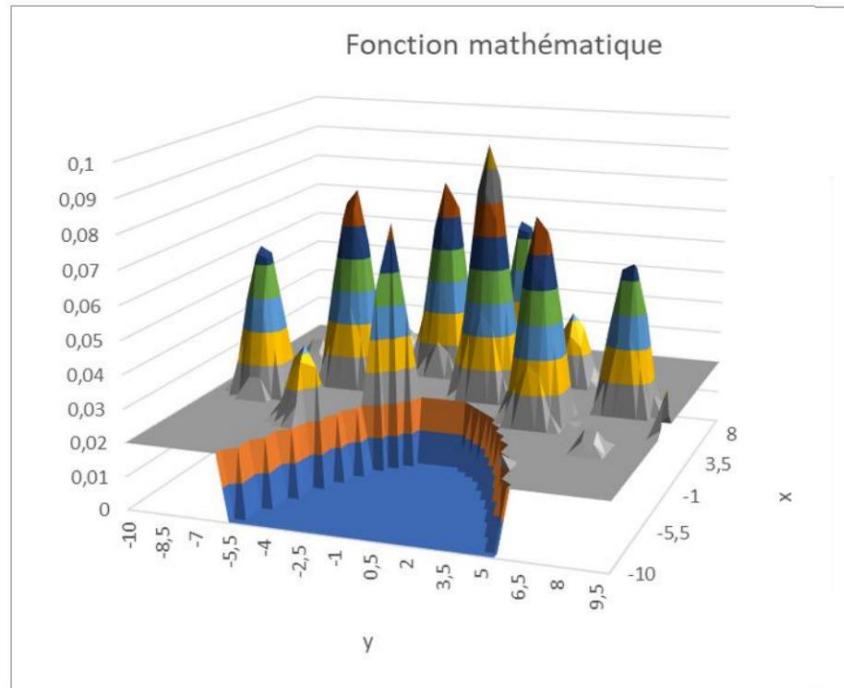
ÿ Local optimization methods (pseudo gradient, simplex, etc.) make it possible to find the local optimum closest to an initial solution

ÿ Random search methods for the global optimum (genetic algorithms, simulated annealing, etc.) are very slow to converge with no guarantee of success.

Optimization

ÿ The hybridization of global and local methods:

- avoids blocking on a local optimum and the need to start from a good solution

- greatly accelerates convergence speed and improves quality
    solutions found

- allows you to find solutions that are difficult to imagine a priori
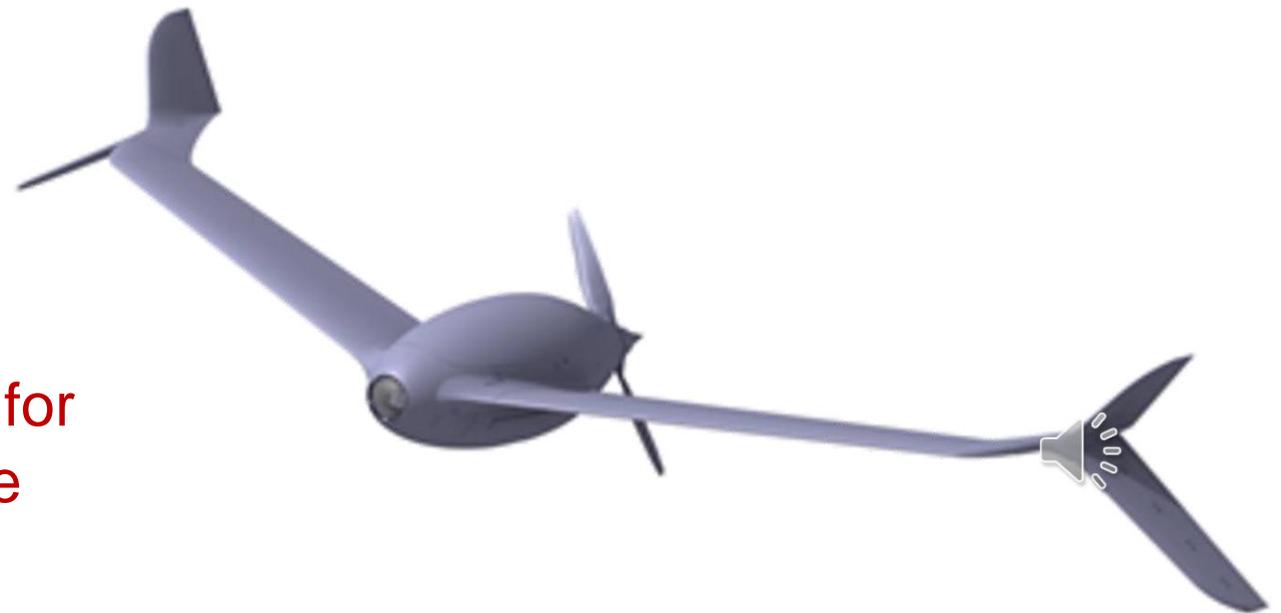
+ 30% elongation (> 500 Km) for
the 4 kg Cabiota electric drone

Mont Carlo Simulation

ÿ Approximate calculation method using random processes to solve multiple problems in all areas:

Integral calculus, particle physics, mechanical dimensioning, reliability, financial management, etc.

ÿ Consists of simulating a configuration of random variables used in a calculation, to obtain results, then repeating the operation a large number of times, in order to obtain a distribution of the results

Variables aléatoires

X_1 X_2 X_n Modèle de calcul $Y_1..Y_n$
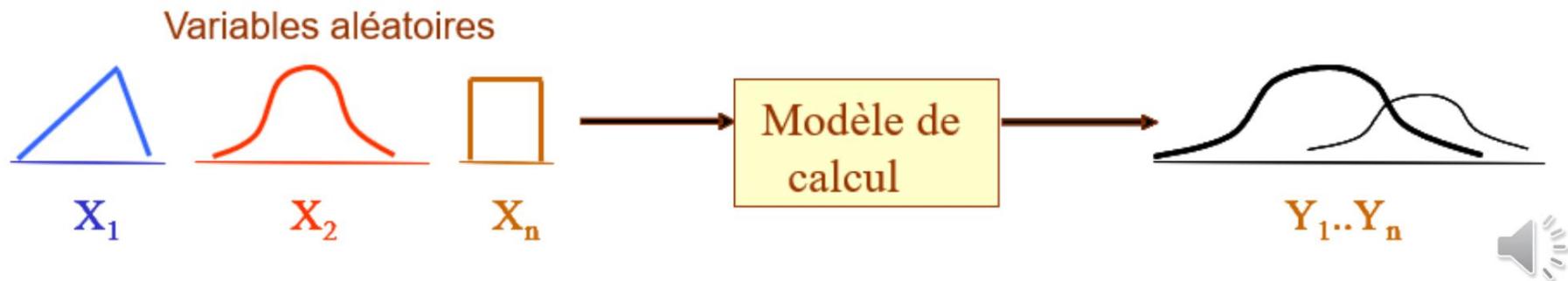
Cab Designer

ÿ Hybrid optimization software *(genetic algorithms + simplex)* and Monte-Carlo simulation

ÿ Easy to use in the Excel environment

ÿ Connects to calculation software running under Windows via their command prompt

ÿ Performs optimizations from Monte-Carlo simulation results.

   Carlo in reasonable times

ÿ This allows us to resolve a whole range of new problems of a deterministic and random nature

Cab Designer

ÿ Optimization

- Decision variables (< 100 spreadsheet parameters): real, integer, binary, alphanumeric, permutation, combination with or without repetition and arrangement

- Constraints: penalty or inside point method

- Number of AG loops and simplex steps at each loop (or at some)

- Starting from previous results or reset variables

- Ability to plot a 2D or 3D curve of the performance function as a function of one or two real or integer parameters

Cab Designer

ÿ **Simulation**

- Random variables: Beta, Binomial, Chi-square, Erlang, Exponential laws, Gamma, Geometric, Gumbel, Hypergeometric, Lognormal, Normal, Standard Normal, Pareto, Pearson, Poisson, Student, Triangular, Uniform, Gamma Variance, Weibull …

- Results: mean, standard deviation, quantiles, probability of exceeding a threshold, etc.

Cab Designer

ÿ **Generic coupling method**

- **GRIF :** optimize the design and logistical support of systems

- **Xfoil :** improving the aerodynamic performance of aircraft

- Any calculation software running under Windows

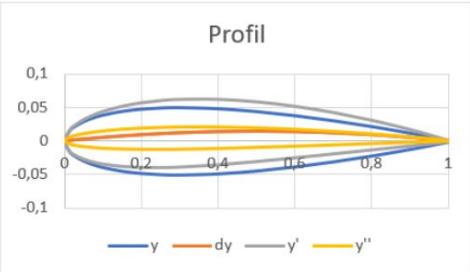|	A	B	C	D	E	F	G	H
1	Calculation	Write	Write	Write	Write	LaunchWait	Read	Calculation
2	All	C:\xfoil\Profil.dat	C:\xfoil\commands.bat	C:\xfoil\xfoil.bat	C:\xfoil\result.txt	C:\xfoil\xfoil.bat	C:\xfoil\result.txt	All
3			LOAD C:\xfoil\profil.dat	del C:\xfoil\result.txt				
4		1 0.000359601264276504	oper	C:\xfoil\xfoil.exe < C:\xfoil\commands.bat			XFOIL Version 6.99	
5		0.95 0.00321124041976394	visc80000					
6		0.9 0.00585729014370084	0				Calculated polar for:	
7		0.8 0.0105534668319901	iter					
8		0.7 0.0144760326536429	100				1 1 Reynolds number fixed Mach number fixed	
9		0.6 0.0176184967685487	pacc					
10		0.5 0.0198954547841711	C:\xfoil\result.txt				xtrf = 1.000 (top) 1.000 (bottom)	
11		0.4 0.0211597130281859					Mach = 0.000 Re = 0.080 e 6 Ncrit = 9.000	
12		0.3 0.0211509170734039	Cl 0.5					
13		0.25 0.0205491951183253	quit				alpha CL CD CDp CM Top_Xtr Bot_Xtr	
14		0.2 0.019440755220538					----- -------- --------- --------- -------- -------- -------	
15		0.15 0.0176988314102052					4.297 0.5000 0.03545 0.02671 -0.0095 0.1023 1.0000	
16		0.1 0.0150870559267978						
17		0.075 0.0133153935581655						
18		0.05 0.0110539727549372						

Profil

Xfoil address : https://web.mit.edu/drela/Public/web/xfoil/

ÿ The first columns of the calculation file correspond to actions processed sequentially at each evaluation: calculation, writing or reading of text files (.txt, .dat, .bat), launching of files (.bat)
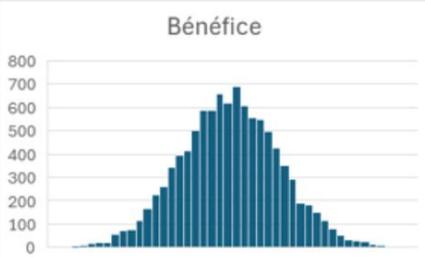
Cab Designer

ÿ **Optimization from simulation results** • Average value, quantile, probability of exceeding threshold, etc.

Dimensionnement d'un stock de vente

RANDOM	1	2	3	4	3	4
Name	Coût_A	Coût_B	Coût_C	Prix_A	Prix_B	Prix_C
Law	Triangular	Uniform	Normal	Pareto	Triangular	Normal
Parameter 1	2	2,5	5	2	5	8
Parameter 2	1	4,5	0,3	1	4	2,5
Parameter 3	5				8	
Parameter 4						
Parameter 5						
Value	2,79472	3,216257	4,628486	1,197603	5,947217	12,48693

DATA	1	2	3
Name	Nb_A	Nb_B	Nb_C
Type	Integer	Integer	Integer
Min / k	0	0	0
Max / n	100	100	100
Init / End	99	16	24

Bénéfice [679,7664] $Nb\_A * (Prix\_A - Coût\_A) + Nb\_B * (Prix\_B - Coût\_B) + Nb\_C * (Prix\_C - Coût\_C)$

$Nb\_A + Nb\_B \leq 60$

$Nb\_A + Nb\_B + Nb\_C \leq 100$

Bénéfice
(histogram with y-axis 0, 100, 200, 300, 400, 500, 600, 700, 800)

RESULT

Criteria [679,7664] Max

Constraints

[60] >= [19]

[100] >= [100]

Penality   Factor: [1,00E+03]

Objective [679,7664]

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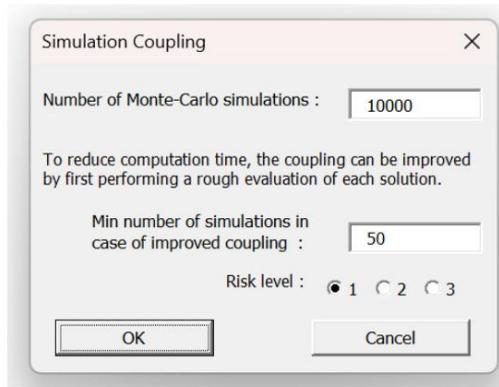
Cab Designer

ÿ **Optimization from simulation results**

- Optimization requires a lot of simulations:

  5000 evaluations * 5000 simulations = 25 million for a typical application in average value

- An algorithm based on the OCBA principle makes it possible to considerably reduce calculation times by a ratio of 10 to 50

 16.5 for this case study, which goes from 2 hours to 7 minutes

Simulation Coupling ✕

Number of Monte-Carlo simulations : 10000

To reduce computation time, the coupling can be improved by first performing a rough evaluation of each solution.

Min number of simulations in case of improved coupling : 50

Risk level : ⦿ 1 ◯ 2 ◯ 3

OK   Cancel

Optimal Computing Budget Allocation (OCBA)

N1/N2 : 0,16735537 $=(\sigma1/(M-m1))^2/(\sigma2/(M-m2))^2$

m1 :	4		m2 :	5		M :	6,2
σ1 :	0,3		σ2 :	0,4			
N1 :	16,7355372		N2 :	100			

Rough assessment possibly followed by a more or less fine assessment
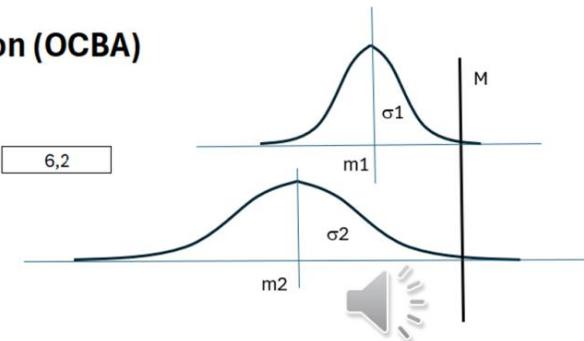
Even risk of losing a good solution

Application examples

ÿ Numerous examples offered by the tool:
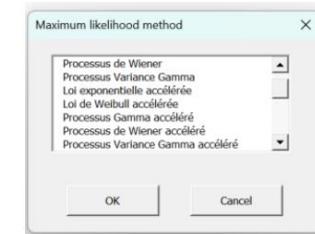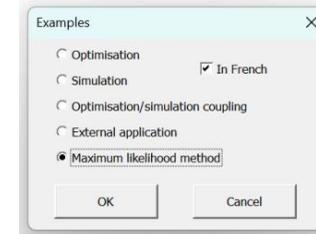
ÿ **Adjustment (maximum likelihood)**

Processus de Wiener non stationnaire accéléré

- Likelihood higher than that obtained by existing tools (hybrid method)

- Confidence intervals estimated from the Fischer matrix

Application examples

ÿ **Test plan** (optimization/simulation)

Plan d'essais accélérés de fiabilité $\sum_{k=0}^{m} C_n^k (1-p)^{n-k} \leq \alpha$

Durée de la mission T :	100000	hr				
Objectif de fiabilité à T :	0,95					
Niveau de confiance de l'estimation :	60%					

Nombre de pièces n :	24	
Type d'essai :	1	
Coût d'une pièce :	250	€
Coût de l'essai :	20000	€
Coût si le test échoue :	500000	€
Coût global :	26000	€

Type d'essai :	1	2	3
Facteur d'accélération :	1	8	25
Coût horaire (€):	0,2	0,5	3

Fiabilité réelle (Weibull)
β :	2,5
σ :	800000

Nombre de pannes : 0   Succès de l'essai : VRAI

Pannes :	1er	2ème	3ème	4ème	5ème
t(hr) :	396011	422359	428989	434050	473866
1	600470	600470	600470	600470	600470
2	893665	893665	893665	893665	893665
3	1211974	1211974	1211974	1211974	1211974
4	883617	883617	883617	883617	883617
5	428989	428989	428989		
6	704088	704088	704088	704088	704088
7	712896	712896	712896	712896	712896
8	1402354	1402354	1402354	1402354	1402354
9	396011				
10	1346445	1346445	1346445	1346445	1346445
11	422359	422359			
12	815321	815321	815321	815321	815321
13	473866	473866	473866	473866	473866
14	1063948	1063948	1063948	1063948	1063948
15	434050	434050	434050	434050	
16	592091	592091	592091	592091	592091
17	1056440	1056440	1056440	1056440	1056440

Optimisation

DATA	1	2
Name	n	Type_essai
Type	Integer	Integer
Min / k	1	1
Max / n	50	3
Init / End	24	1

RESULT		
	Criteria	323250	Min
	Objective	-323250	

Simulation

RESULTS	1
Name	Coût_global
Chart	Yes
Output	Average
Parameter	
Value	323250

Plan optimization from test sequence simulations

Application examples

ÿ **Reliability network** (coupling with GRIF/ALBIZIA)
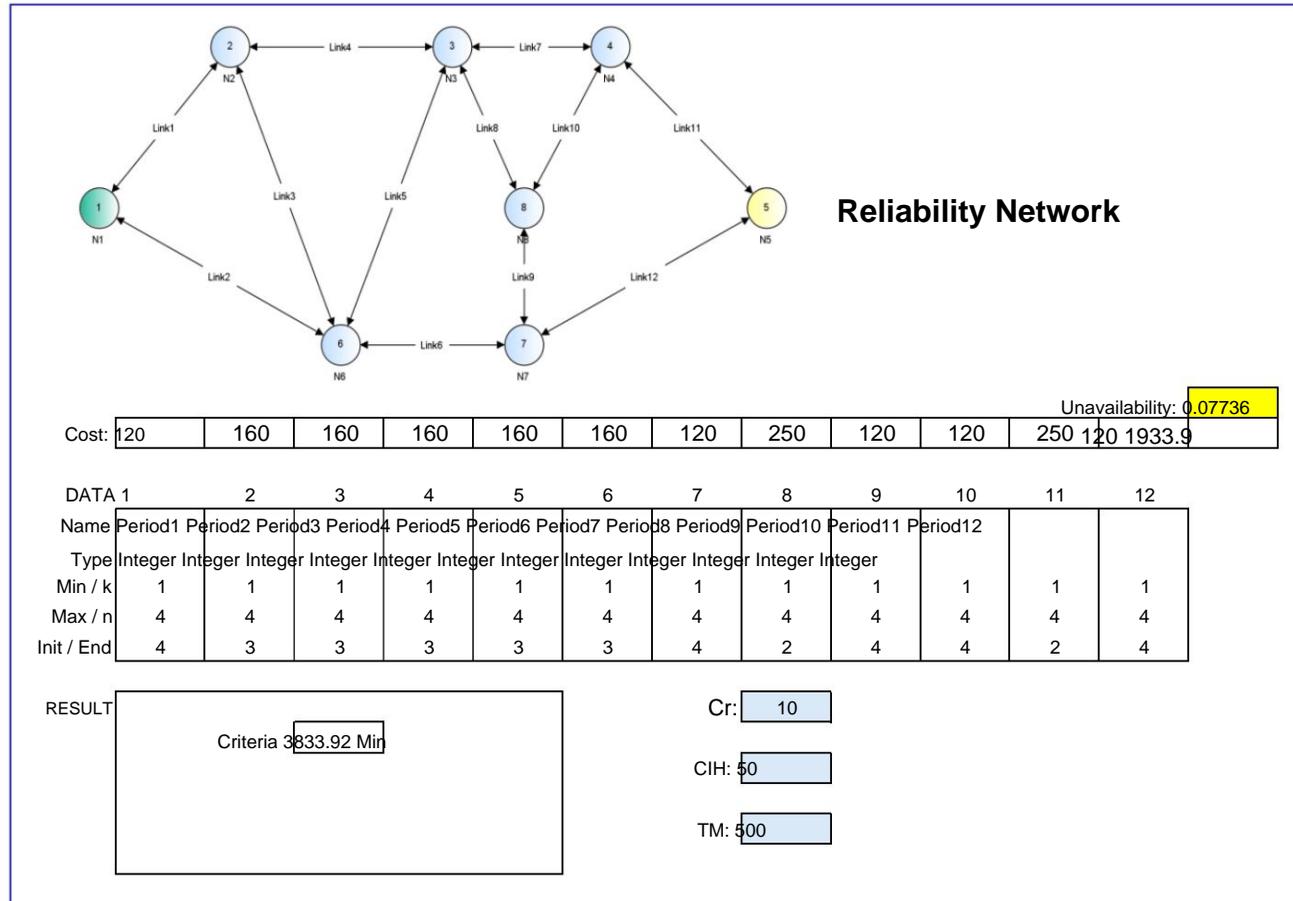
Minimal operating cost by adjusting the maintenance period of each piece of equipment

Application examples

ÿ **Production system** (coupling with GRIF/MOCA-RP)

Production system

Availability
90,024

Cost	
A1	20
A1s	0
A2	20
A2s	0
B	60
Bs	0
Nb_repairers	60
Total :	160
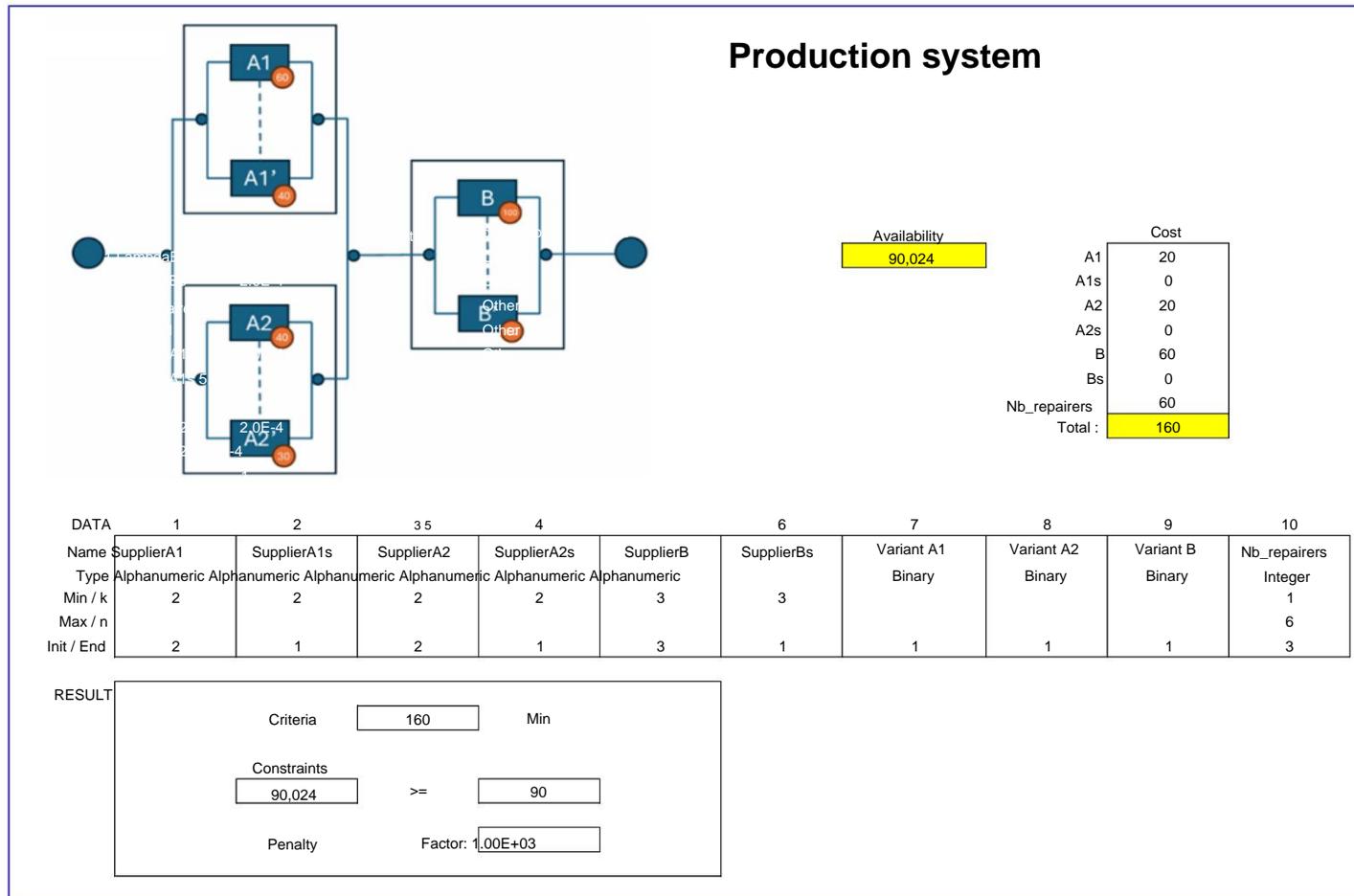
Network of

Stochastic Petri

DATA	1	2	3 5	4		6	7	8	9	10
Name	SupplierA1	SupplierA1s	SupplierA2	SupplierA2s	SupplierB	SupplierBs	Variant A1	Variant A2	Variant B	Nb_repairers
Type	Alphanumeric	Alphanumeric	Alphanumeric	Alphanumeric	Alphanumeric	Alphanumeric	Binary	Binary	Binary	Integer
Min / k	2	2	2	2	3	3				1
Max / n										6
Init / End	2	1	2	1	3	1	1	1	1	3

RESULT

Criteria	160	Min
Constraints		
90,024	>=	90
Penalty	Factor: 1.00E+03	

Minimal operating cost by ensuring 90% production capacity

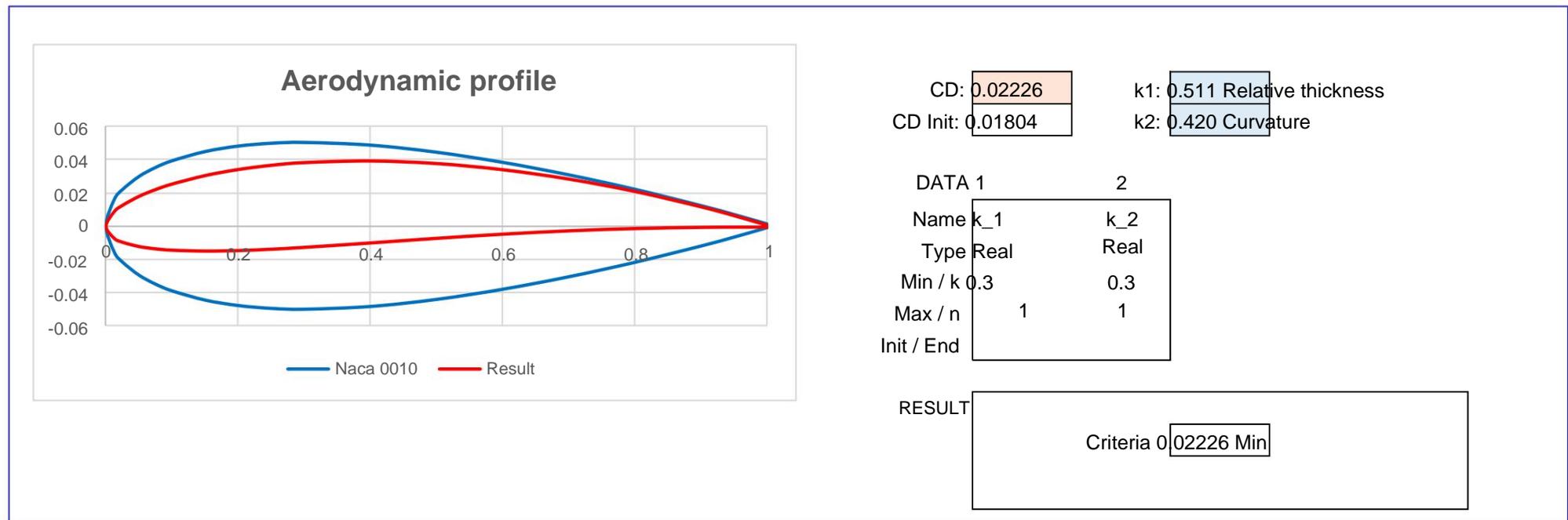# Application examples

ÿ **Shape optimization** (coupling with XFoil)

Aerodynamic profile

Naca 0010 — Result

CD: 0.02226   k1: 0.511 Relative thickness
CD Init: 0.01804   k2: 0.420 Curvature

DATA	1	2
Name	k_1	k_2
Type	Real	Real
Min / k	0.3	0.3
Max / n	1	1
Init / End		

RESULT

Criteria 0.02226 Min

Minimizing the drag coefficient (CD) by varying the relative thickness (k1/10) and the curvature (k2 × 10) from the standard symmetrical profile Naca 0010 (at the angle of incidence giving a lift coefficient CL equal to 0.5)

Application examples

ÿ **Industrial case** (R&D Cab Innovation + Total + CNES)

Constellation of satellites

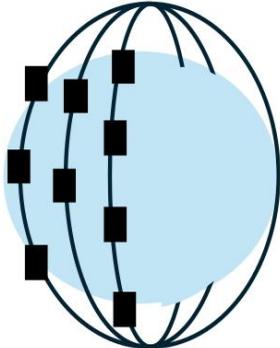| DATA	1	2	3
Name	Emport_Ariane	Delays_Launch_Vega	Emport_Vega
Kind	Integer	Real	Integer
Min / k	22	1488	1
Max / n	32	10000	7
Init / End	31	1537.03	4

	m	s
Available time: 112009.	66 5565.13	
Nb_Sat_lances: 49	1.75	12.46

Mission duration: 131,400 hours

Availability: 0.85243276

RESULT

| Criteria | 491,7484 | Min |

Constraints

| 85.24% | >= | 85% |

Penalty   Factor: 1.00E+03

GRIF/

MOCA-RP

Optimization of the deployment and renewal of a constellation of satellites placed on 6 orbital planes.

Availability greater than 85% (> 21 operational satellites per plan)
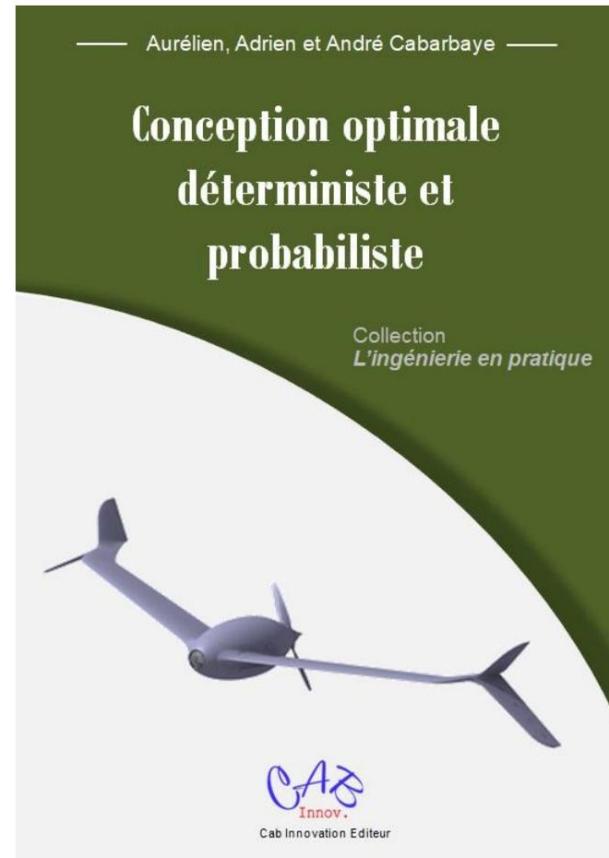
Machine Translated by Google

Conclusion

ÿ Optimization has become essential for developing high-performance and innovative products and services.

ÿ It must be implemented by engineers and analysts who are the only ones who can correctly formalize their problems

ÿ Cab Designer software attempts to meet their expectations by making the most effective optimization and simulation techniques available to everyone, with generic tools applicable to all engineering fields.
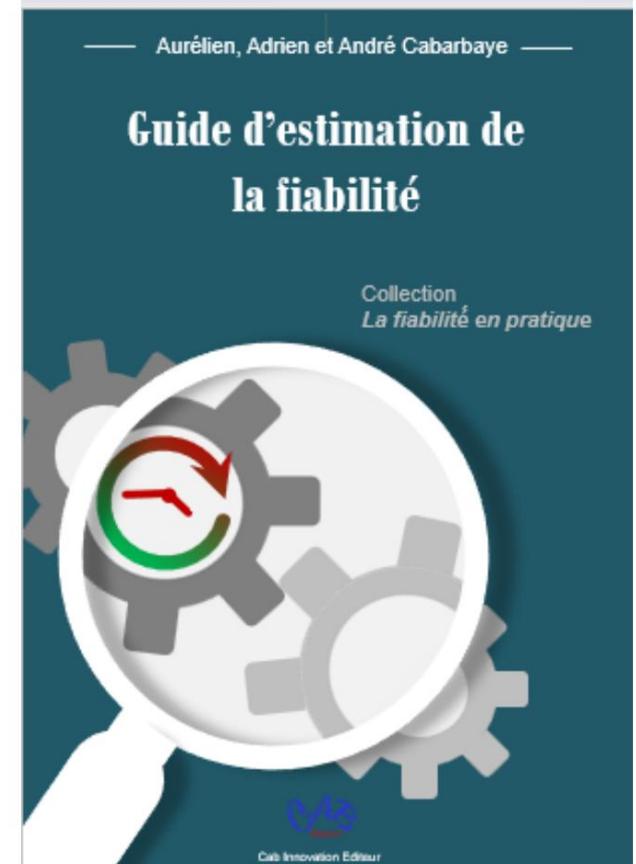
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