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LARGE-SCALE ASSESSMENT OF FINANCIAL CONSEQUENCES OF RISKS: THE CASE OF THE ARIANE SPACE PROGRAM

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ABSTRACT

The European Ariane space program involves 30 launches of one or more satellites each over a number of years. A massive effort was developed in order to register all the risks linked to this program and to evaluate their financial consequences. A complex model was developed for this purpose, pushing Microsoft® Excel's and Crystal Ball®'s capabilities to their limits. The principles of the model described in this paper may be applied to any other large-scale project.

1 INTRODUCTION

In August 2004, I was invited to give a one-day conference on Risk Management to several EADS managers from the Ariane space program. A few weeks later, they asked me to participate, as a risk consultant, to the development of a thorough risk model for this program. The Ariane Production program is a program of 30 satellite launchers, which are programmed to fly in the coming years.

The objective of the model was to list all the possible risks, with their probabilities and financial consequences, and to evaluate, through a Monte Carlo simulation, the cumulative financial consequences of these risks.

Of course, the model was supposed to evaluate, in a similar manner, the financial consequences of a number of subsets of risks, e.g. of the risks of a given stage of the launcher, or the risks linked to subcontractors.

It was decided to develop the models in Excel, using Crystal Ball for Monte Carlo simulations. Since version 7 was not yet on the market when this project began, version 5.5 was used for this development.

2 PROBLEMS LINKED TO THE MODEL SIZE

As may easily be imagined, the risks linked to a program of satellite launchers were numerous and implied the definition of more than 2,000 assumptions, clearly more than is advised to use with Crystal Ball.

Moreover, with such a large set of assumptions, the sensitivity analysis becomes a problem, since it will be quite difficult for any single assumption to have a significant effect on a given forecast.

Last, although the model had to be quite big, it was felt necessary to build it in such a way that potential users would not be overwhelmed by the model complexity, if we wanted them to be reactive enough and participate in the model validation. There was therefore a strong emphasis on building a model with a structure understandable by all, so user-friendly that there would be no user resistance.

In the first part of this paper, we shall describe the model itself. In the second part, we will explain how the preceding three problems (number of assumptions, sensitivity analysis and model complexity) were solved.

A non-disclosure agreement was of course signed for this development. All the screens you will see in this paper relate to a "demonstration" version of the model, where we modified all the labels and all the financial values. The only thing which is not modified is the description of the model structure.

3 MODEL DESCRIPTION

It is not possible, due to the NDA, to show here the detailed structure of the model. We shall therefore present only the general structure of the model.

An initial sheet documents the model, listing the following sheets and explaining their purpose. Comments are made about specific features of each sheet. A typical assumption is shown in Figure 1.

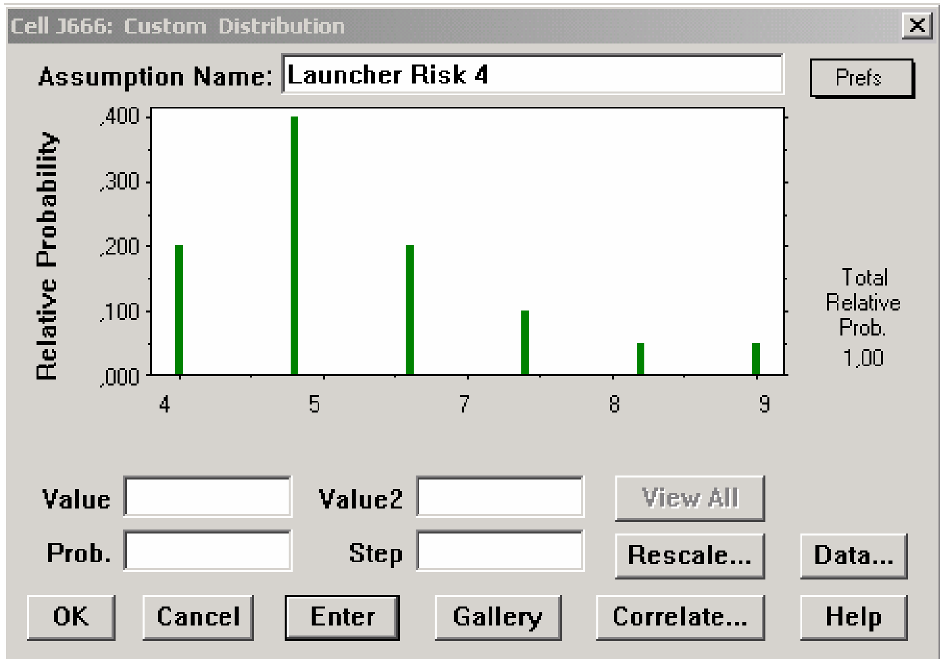


Figure 1: Example of Crystal Ball assumption

The first "operational" sheet lists, ordered by risk category, all the known risks with one risk per row. In each case, the probability of the risk and its cost impact are described. In a first approach, in order to simplify the modeling process, each risk was considered to be a "Yes/No" risk and the cost consequence was a uniform distribution. In order to reduce the number of assumptions in the model, many risks and their consequences were defined using Excel or Crystal Ball functions. It was decided to wait for the results of the initial simulations so that the sensitive variables could be identified, with the objective to be more precise in the future only for the variables with a significant impact (sensitivity) in these simulations.

The second "operational" sheet identifies, for each stage of the Ariane rocket and for each of the 30 launchers, which component is used. Each Ariane launcher is made up, at each stage, of components which are selected in a list. Since the model identifies the risks linked to each component, we have to know which of them was used in which launcher. This sheet is therefore the input sheet: we input the allocation of components to launchers, so that we may estimate through a Monte Carlo simulation the total cost of risks linked to this allocation program. In this second sheet, we also enter our options for the future sensitivity analysis.

The next sheet, "Risk per launcher", combines the two preceding sheets in order to produce a risk, per risk type and per launcher. In this sheet, forecasts are defined by grouping sub-risks of the same type; there are almost 1,000 forecasts in this sheet. The last sheet, "Results", shows percentiles, by steps of 5, for several combinations of risks: rocket stages, product groups, launchers,…

Altogether, this model currently requires around 4.5 MB and runs 10,000 iterations in around 20 minutes.

4 THE SENSITIVITY ANALYSIS

The sensitivity analysis was a problem. The first problem was that, given our several hundred assumptions, we expected that very few of them would have a significant impact on any of the major forecasts. A solution was therefore to group them by summing subsets of assumptions and define these sums as forecasts. This is where our second problem came: Crystal Ball does not allow us, since version 5, to incorporate forecasts in a sensitivity analysis. In version 4, when a sensitivity analysis was defined, you could check/uncheck assumptions and forecasts. This feature disappeared with version 5 and has not come back with version 7.

It was therefore necessary to write a VBA macro, using the Crystal Ball library, which extracts a set of selected forecasts to a new Excel document, calculates the correlations, and generates a sensitivity analysis. The good point about this was that, contrary to the usual sensitivity analysis settings, this macro could run after the simulation, and you could run it – changing the sensitivity parameters – as many times as you wanted.

5 MODEL OUTPUT

Of course, all the standard outputs of Crystal Ball may be used with this model, forecast charts, overlay graphs,…

But this was not sufficient for the analyses required by this model. We therefore developed a macro for a detailed sensitivity and weight (we will describe this shortly) analysis.

The screen on the right (Figure 2) allows the user to parameter his sensitivity/analysis. The model has 12 product categories and 4 domain criteria.

The analysis parameter (J45) is a pull-down menu where you select any of the values from I45 to I61. The fact that we have a "1" here means we pulled down the I57 value which has a value of "1" formatted there with a custom format.

The analysis parameter may therefore be any product, or any domain, or "Total".

The analysis (G65) may be "Macro" or "Micro" and it is expressed as a function of (G66) Product or Domain fields.

Basically, it means we may lead a sensitivity analysis of 18 different results, macro or micro, according to products or domains, and including (depending on the 1's in column I) the forecasts from any selection of products or domains.

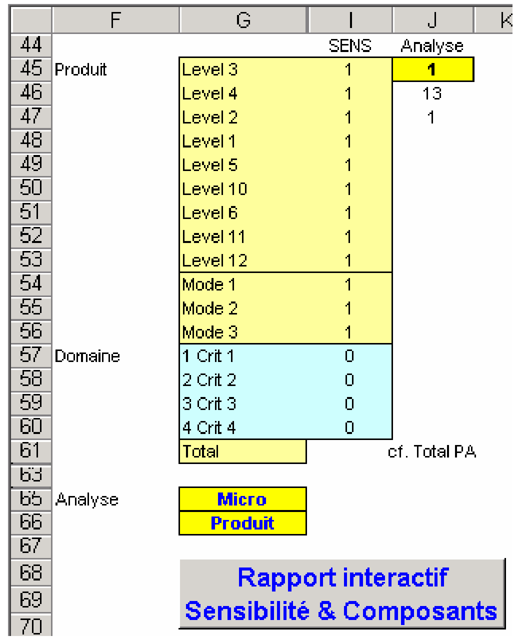


Figure 2: Macro for sensitivity and weight

When all the settings are made, a click in the report button (rows 68:69) will run a macro which exports all the results and creates the reports presented in the next section.

Of course, given the high number of forecasts, this report will turn out to be impossible if more than 250 of them result from the preceding selection, since there are only 256 columns to export to in Excel. If this situation arises, the macro will show an error message giving the user the possibility to exclude from the analysis any forecast with a mean value smaller than a value he specifies.

6 MODEL REPORTS

The report macro produces three graphs, reproduced in Figure 3. The first graph represents the sensitivity analysis with the fifteen forecasts which have the biggest impact, in terms of volatility, on the selected result.

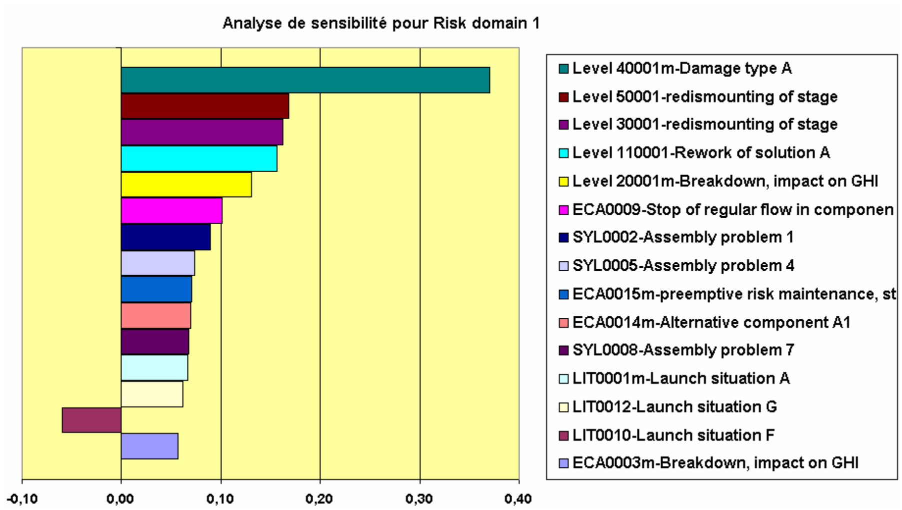
The second graph (second and third figure on the next page) represent the major 15 components of the variable under analysis, "Risk domain 1" in this case. These fifteen major components are the fifteen forecasts which are a part of "Risk domain 1" and account for the biggest part of the financial cost of "Risk domain 1."

A forecast which would have an important share of this cost, and little volatility, could be high up in the second graph and absent from the first graph. This would be much more unlikely the other way round: if a forecast has a high sensitivity impact, it cannot have a high volatility and represent only a small part of the financial cost of the variable under analysis; if the sensitivity impact is large, it implies that this variable should represent a significant (but not necessarily in the fifteen first values) part of the "Risk domain 1" cost.

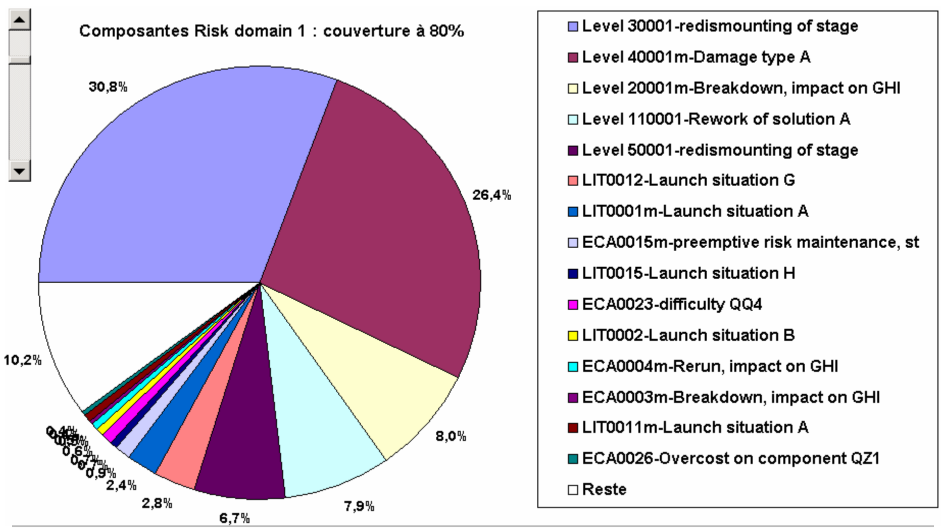
You will observe, in the second graph, a scroll bar through which the user selects the percentage of the risks he intends to cover. The title of this graph indicates the selected percentage. As you slide the scroll bar, the pie chart adapts in real time. This allows the user to see how the pie chart evolves, depending on the financial coverage he is thinking about.

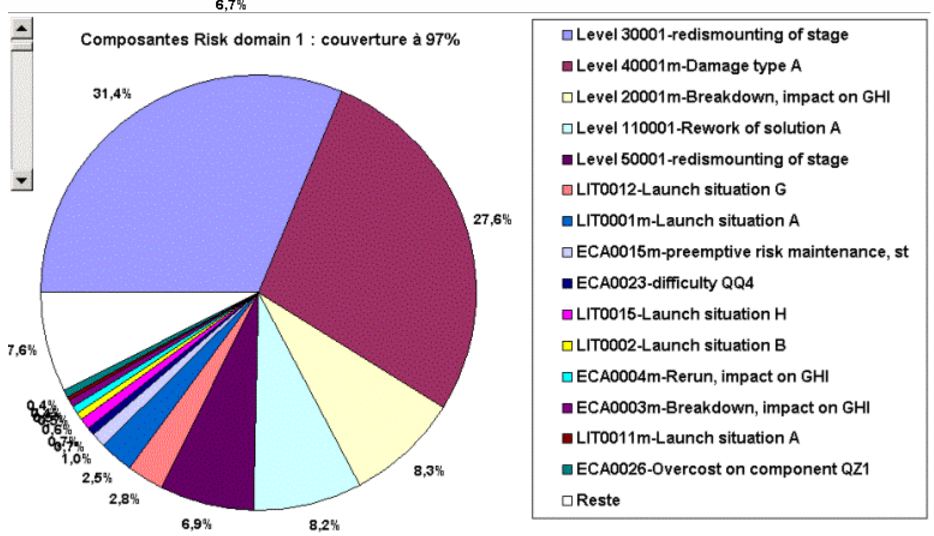
The third graph shows the cumulative cost for "Risk domain 1". In this case, we see that the cost range between 6,348 M euros and 43,377 M euros (remember that these figures are fictional). An 80% risk coverage costs 16,821 M euros (Figure 4). As happens in most real-life situations, we observe that the last percentage points are very, very expensive.

This third graph has the same scroll bar as the second graph, both bars acting on the same cell. Another macro allows the user to pull down the name of a graph from the Excel name area and automatically see the related graph at an optimal scale.



Sensitivity graph, as designed by the program macro





"Major components" graph, as designed by the program macro (steps 1 and 2)

Figure 3: Result graphs from program macro

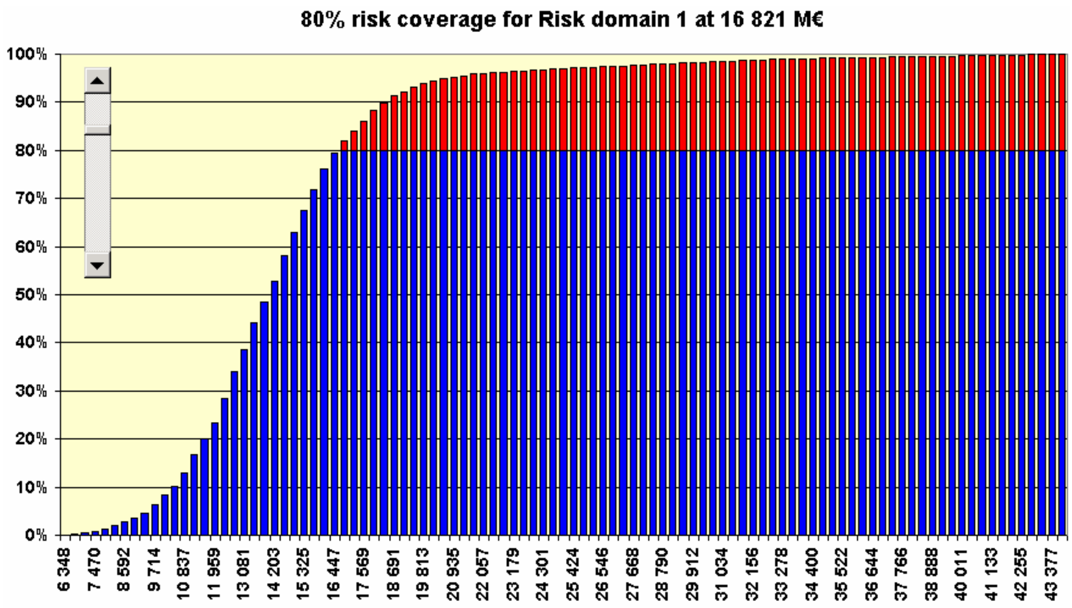


Figure 4: "Cumulative cost" graph, as designed by the program macro

7 CONQUENCES OF THIS MODEL

An exhaustive procedure was developed for the validation of this model, each risk manager being asked to validate all the risks under his responsibility.

Since the model clearly identified the most important and most volatile risks, each risk which ranked high in both lists was analyzed in detail, so that its distribution and cost consequences could be evaluated as precisely as possible.

A reporting process was organized so that each risk manager could regularly update the information relative to the risks under his responsibility. An update procedure was set in order to consolidate these data in the main model.

The whole process has been very valuable in assessing the risks and their consequences, and in helping concentrate on the major issues.

8 ACKNOWLEDGEMENTS

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- Bernard Loez, EADS, Vice President, Chief Restructuring Officer
- Jean-Denis Lefebvre, EADS, Ariane 5 Program Control Manager
- Christophe Parmenon, EADS, Ariane5 Production Program Control Manager

BIOGRAPHY

Professor Thiriez teaches at the HEC School of Management (Information Systems and Decision Analysis department), where he is in charge of the Management Science programs. He is also the CEO of Logma SA and of Editions MEV(distributor of Crystal Ball in France), which he both funded in 1980. After his Ph.D. in Operations Research at MIT, Professor Thiriez began his career as an Assistant Professor in the Aeronautics & Astronautics department of MIT, teaching at the Sloane School, before returning to France. During his career, he has published 25 books and more than 300 articles and papers. Contact : thiriez@hec.fr